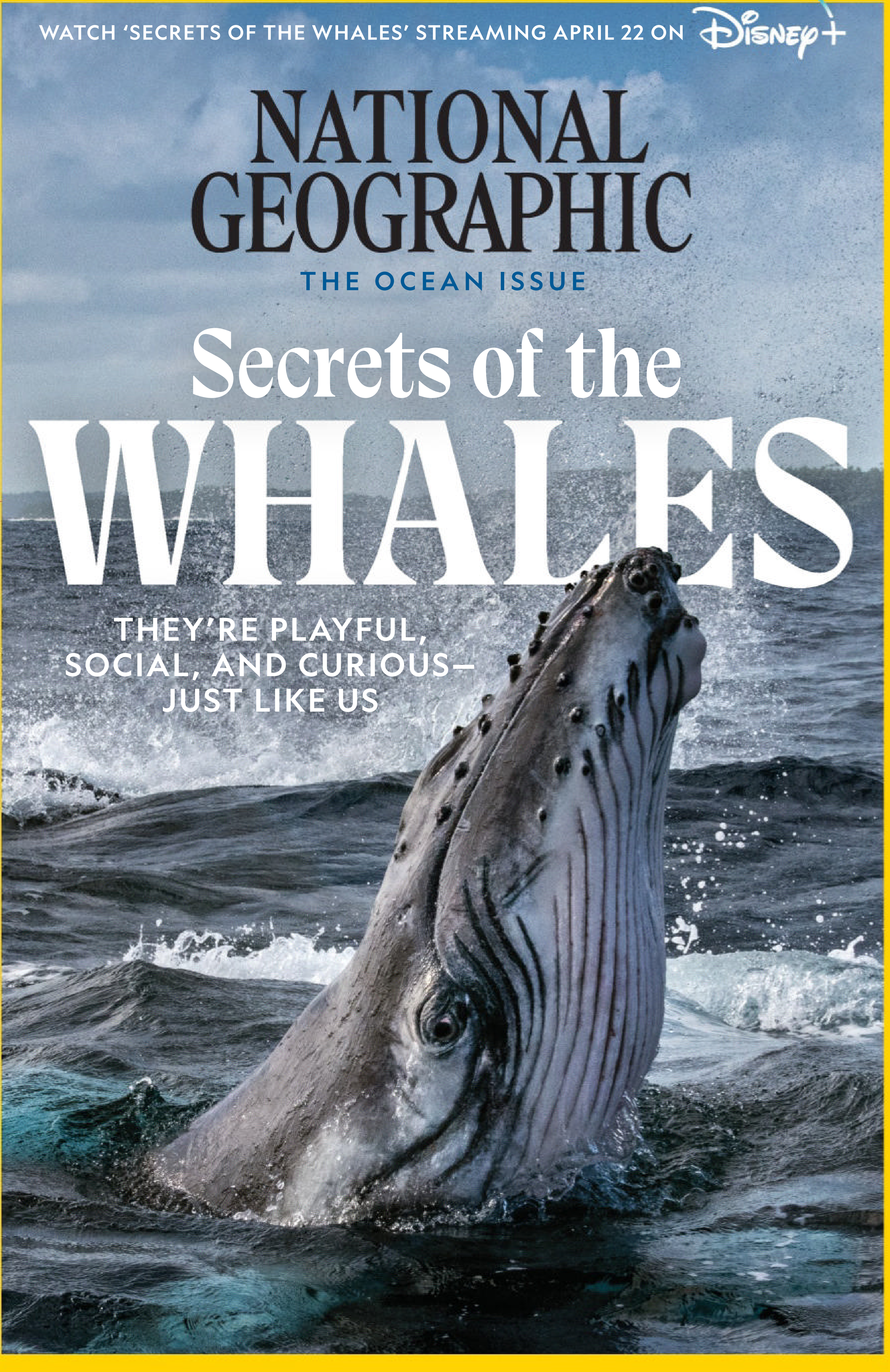
05.2021

WATCH 'SECRETS OF THE WHALES' STREAMING APRIL 22 ON Disney+

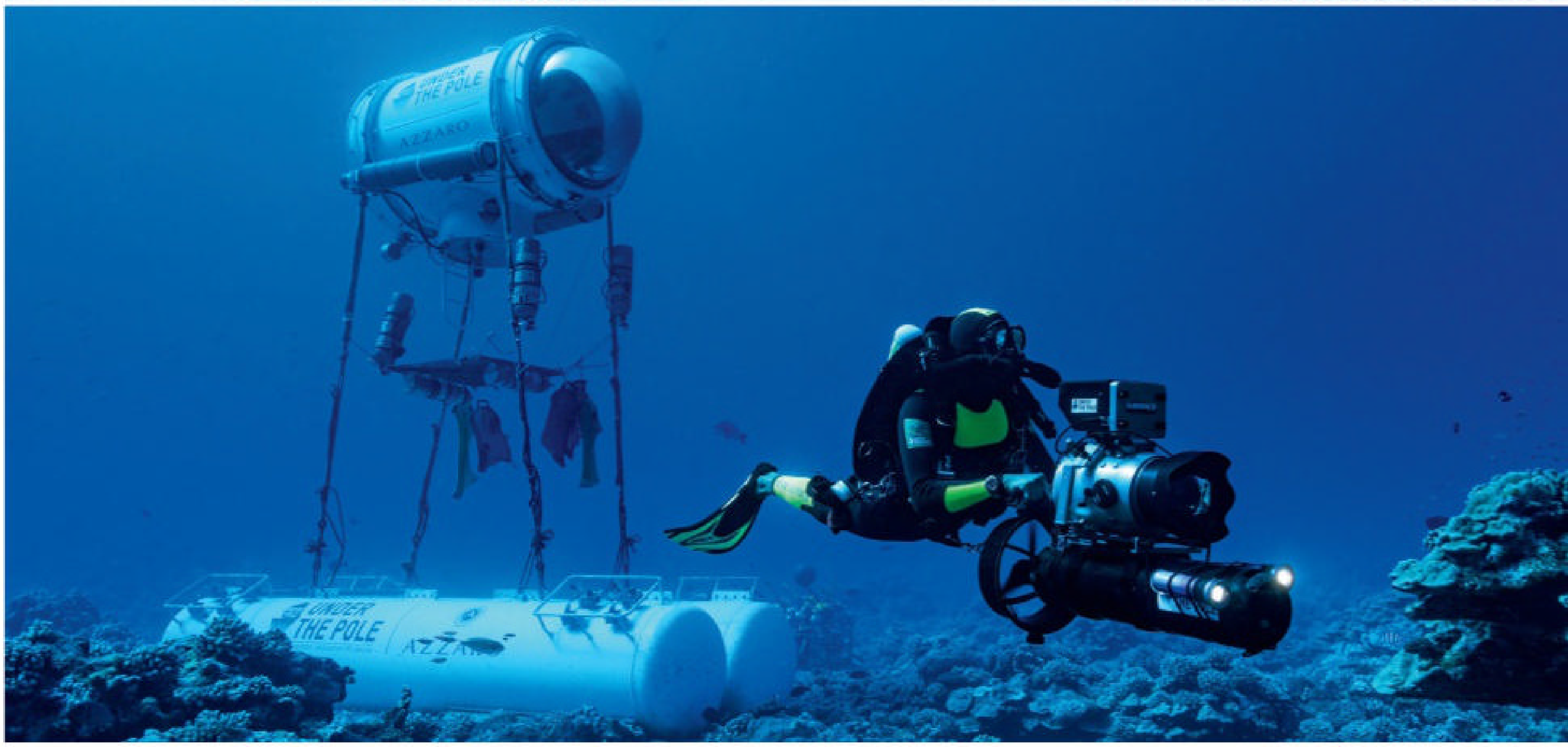
NATIONAL GEOGRAPHIC

THE OCEAN ISSUE



Secrets of the WHALES

THEY'RE PLAYFUL, SOCIAL, AND CURIOUS—JUST LIKE US


UNDER THE POLE
AZZARO
UNDER THE POLE
AZZARO

NATIONAL GEOGRAPHIC AND ROLEX
PERPETUAL PLANET EVEREST EXPEDITION

MICROBIOLOGIST JOSEPH COOK

DEEPSEA UNDER THE POLE
GHISLAIN BARDOUT

PERPETUAL PLANET

Over the course of the past century, the Rolex Oyster has evolved to meet the demands of explorers and expeditions as they push further into the unknown, helping to advance knowledge of our planet. Our commitment to exploration remains steadfast as the necessity to preserve the natural world, and the systems that sustain life, becomes paramount. Today, with a renewed sense of urgency, Rolex supports the individuals and organisations finding solutions to safeguard the Earth for future generations. Alone we can go far. But only together can we make the planet perpetual.

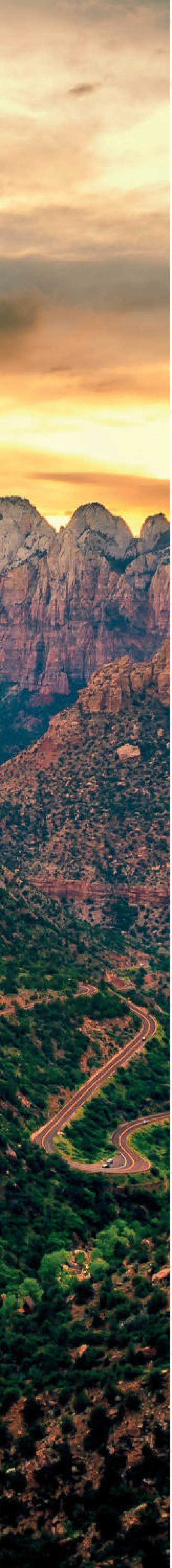
Discover more on rolex.org

#Perpetual

OYSTER PERPETUAL EXPLORER II

ROLEX

PAID CONTENT CREATED WITH HYUNDAI



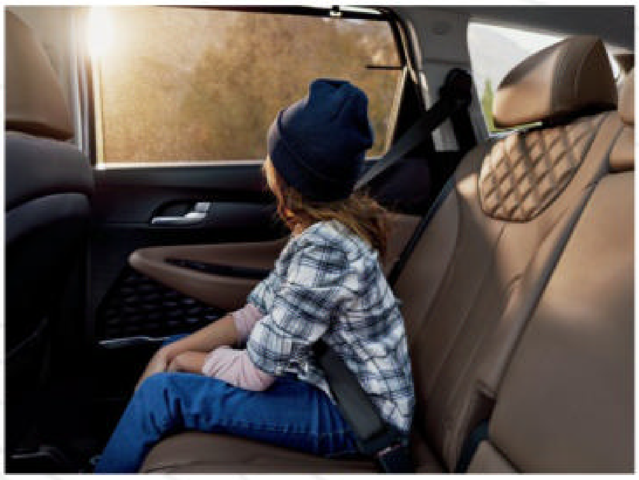
PAID CONTENT CREATED WITH HYUNDAI

TAKE A FAMILY *OFF-ROAD* TRIP

National Geographic and Hyundai are teaming up to bring you Outside Academy—an educational, immersive augmented reality (AR) experience designed to empower you and your family to discover some of America's most iconic national parks.

At Outside Academy, you'll be able to explore and learn about these incredible landscapes like never before. Covering subjects like biology, history, wildlife, travel, and more, you'll uncover the wonders of these national parks and leave feeling inspired to make your own discoveries.

Thanks to the first ever 2021 SANTA FE Hybrid, you can learn about America's most iconic national parks, while respecting the environment around you. And with HTRAC All Wheel Drive, the SANTA FE Hybrid is up for even the most epic of family adventures. Taking education on the road, it's your journey in the first ever SANTA FE Hybrid.



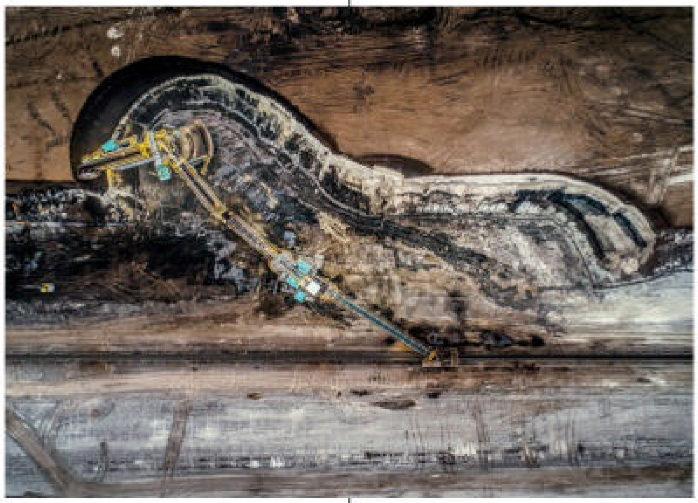
To start exploring Outside Academy, visit
NATIONALGEOGRAPHIC.COM/OUTSIDE-ACADEMY

This is paid content created with Hyundai. This content does not necessarily reflect the views of National Geographic or its editorial staff.

CONTENTS

On the Cover
In South Pacific waters, a humpback whale calf focuses on photographer Brian Skerry, and vice versa. Skerry has spent years observing the distinctive behaviors and traditions of many cetacean species.
BRIAN SKERRY

EARTH DAY | SPECIAL REPORT



6

PROOF

Mining Marks a Landscape

Viewing mines from above, a photographer captures the results of extracting coal to fuel electric power plants.

PHOTOGRAPHS BY TOM HEGEN

15

THE BIG IDEA

Conservation's Popularity Contest

Wildlife funding and advocacy focus most on charismatic species. Is it time to rethink that approach?

BY CHRISTINE DELL'AMORE

ATLAS

Ice Odyssey

A huge Antarctic iceberg posed a risk to an island wildlife preserve.

BY MARTIN GAMACHE AND SARAH GIBBENS

ALSO

Wandering Rocks
Earth Day Inspirations

32

EARTH DAY

Bridging Cultures, Causes With Music

Cellist Yo-Yo Ma pairs concerts with activist events on environmental and other issues.

BY CLAUDIA KALB

THROUGH THE LENS

Fleeing the Flood

As waters threatened rare giraffes' habitat, former enemies joined forces to move them via a modern-day ark.

BY ANNIE ROTH

ALSO

Green Chandelier
Ink From Pollution

FEATURES

Secrets of the Whales
Some dolphins and whales have their own cultural traditions and dialects, characteristics once thought to be unique to humans.
BY CRAIG WELCH
PHOTOGRAPHS BY BRIAN SKERRY
.... P. 40

EARTH DAY TV

All episodes of the series *Secrets of the Whales* will premiere April 22 on Disney+.

Planet Ocean
About 70% of Earth's surface is ocean. This is how it's connected.
BY MATTHEW W. CHWASTYK AND IRENE BERMAN-VAPORIS
.... P. 80

Rescuing Reefs
Images made years apart show how warming oceans harm corals.
BY JENNIFER S. HOLLAND
PHOTOGRAPHS BY DAVID DOUBILET AND JENNIFER HAYES
.... P. 86

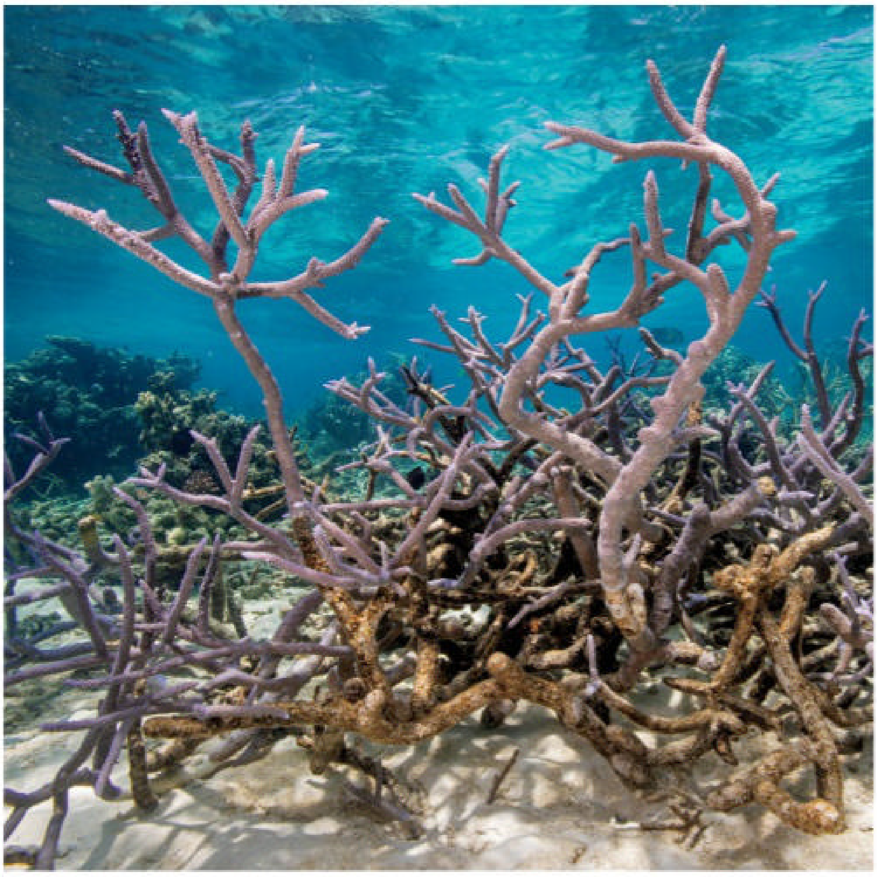
28 Days Under the Sea
Diving on the floor of the Mediterranean, four explorers found amazing life-forms.
STORY AND PHOTOGRAPHS BY LAURENT BALLESTA
.... P. 108

Searcher of the Deep
Decades after locating the wreck of the *Titanic,* Robert Ballard still hunts for cultural and scientific treasures.
BY RACHEL HARTIGAN
.... P. 132

THE OCEAN ISSUE

Hope for Solving Our Seas' Problems

BY **SUSAN GOLDBERG** PHOTOGRAPH BY **DAVID DOUBILET**



THE WORLD'S OCEANS, more than 70 percent of the Earth's surface, are rife with problems: Overfishing, warming and acidifying waters, plastic pollution, a loss of abundance and diversity.

Finding solutions, or even reasons for optimism, can seem a daunting task. But that's what we seek in this special issue. It's dedicated to our seas, the people who explore them, and the creatures that inhabit them—from enormous whales to the tiniest corals.

To care about the ocean in the 21st century is to feel conflicted: despairing what's been lost, optimistic about what we can save. To discuss this tension, I called photographer David Doubilet, who went on his first *National Geographic* assignment 50 years ago. By Doubilet's calculations, he has spent more than 27,000 hours underwater—or just over three of his 74 years.

Doubilet and Jennifer Hayes photographed this issue's story about the changes to coral reefs. In the opening image, you'll see Doubilet holding a photo he'd made on the same reef, in the same spot, in 2009—and what that reef looked like nine years later. Seeing the decline "has been completely draining," he told me. Before, "it was like a bouquet of corals—and I went back to a boneyard."

And yet Doubilet and Hayes remain hopeful that we can turn a lot of this around. They talk about places where the coral's still healthy and is even being used to develop new strains of more resilient coral. And they believe their work documenting all of this—the good and the bad—can inform and inspire.

"The one thing about this time in the sea, it has given me a priceless perspective," he says. "I can make pictures that bear witness. Pictures have this power to educate." But he is careful not to show only pictures that make people feel bad—what he calls "pictures of gloom and doom. We need pictures that also show hope and resilience."

That's the message of this issue: There is reason for hope and a lot that each of us can do. We'd like to help you make a difference. Throughout this issue and across our digital platforms, look for "How You Can Help" boxes and the Planet Possible logo (below). There you'll find ideas for addressing the problems and being part of the solutions.

As Doubilet puts it: "With hope, there's always the ability to change. Whether we choose to drive a hybrid car or not, whether we choose to turn down the temperature, whether we use sustainable energy. Above all, there is hope."

Thank you for reading *National Geographic.* ☐

In 2018 David Doubilet (below) accompanied scientists to an area of Australia's Great Barrier Reef where they sampled corals that had recovered after a devastating bleaching event. Amid patches of death, "the survivor branching corals stand tall and reach for the sun," he notes.

PLANET POSSIBLE

PHOTO: KELLY STREMMEL (DOUBILET)

Introducing DaVinci Resolve 17

Edit and color correct video with the same software used by Hollywood, for free!

DaVinci Resolve 17 is a major new update packed with over 300 features and enhancements! Colorists get new HDR grading tools, AI based magic mask, color warper and more. Fairlight adds lightning fast keyboard and mouse sound editing tools. Editors get new metadata 'slate' view, smart reframing, proxies, keying, Fusion effects and more!

Next Generation HDR and Color Features!

New HDR grading tools, redesigned primary controls, AI based magic mask and more. The new HDR palette lets you create custom color wheels for targeted corrections, magic mask uses the DaVinci Neural Engine to isolate and track objects, and the color warper lets you morph colors in creative new ways! New DaVinci wide gamut image processing gives you even higher quality!

World's Fastest and Highest Quality Pro Audio Tools!

Fairlight features a powerful new engine that supports up to 2,000 realtime tracks with effects, dynamic and EQ. The new context sensitive edit selection tools and updated shortcuts make it even faster and easier to use, especially if you're switching from another system. You can now reverse clips, analyze loudness, view transients, preview video, move automation and more!

Powerful New Edit and Cut Page Features!

A new metadata 'slate' view with bin dividers makes it easy to sort and find clips based on scene, shot, camera, and more! There's also new audio trimming on the cut page, AI based smart reframing for changing aspect ratio, a new portable proxy workflow that supercharges edit performance, render in place, timeline based syncing, compositing, keying, Fusion effects and more!

Fusion Effects, Titles and Transitions for Editors!

DaVinci Resolve 17 lets you save anything created on the Fusion page as an effect, title or transition that can be used on the edit and cut pages! New animation curve modifiers automatically retime animations when clip length is changed, there are new vector shape tools for motion graphics, shared markers, and audio playback with graphical waveform!

DaVinci Resolve .... **Free**

DaVinci Resolve Studio... **US$295**

Free DaVinci Resolve Speed Editor with purchase of DaVinci Resolve Studio

Learn more at www.blackmagicdesign.com

Available for Mac, Windows and Linux

EARTH DAY

NATIONAL GEOGRAPHIC
VOL. 239 NO. 5

MINING MARKS A LANDSCAPE

PHOTOGRAPHS BY
TOM HEGEN

From a helicopter above lignite mines in Germany, a photographer captures the results of extracting coal to fuel electric power plants.

LOOKING AT THE EARTH FROM EVERY POSSIBLE ANGLE

At this coal mine near Dresden, Germany—as at others around the world—excavators move thousands of tons of soil, gravel, and clay to reach fossil fuel deposits.

During and after mining, water runoff can carry toxic concentrations of minerals into drainage ponds. The minerals have been shown to contaminate groundwater.

Angular and symmetrical, excavation and storage sites can suggest artistry, even beauty. Hegen says his images are intended to command attention, not airbrush destruction.

The generation of electricity from coal has fallen significantly in Germany's energy market, and the government plans to phase out the use of coal within two decades.

THE BACKSTORY

A PHOTOGRAPHER MAKES SCARRED MINE SITES LOOK LIKE ABSTRACT ARTWORKS—AND HOPES THEY RAISE AWARENESS.

TOM HEGEN MAKES portraits of the Anthropocene, this current age in which the dominant influence on Earth is human activity. His work often requires observing from above: leaning out of helicopters, operating drones. Taken from these heights, Hegen's series of images show the broad effects of receding glaciers, exploited farmland, polluted quarries—and here, coal mines in Germany, Hegen's homeland.

Some mines are still operating; others, spent and shut down. The lignite coal here is almost always buried, requiring industrial excavation that can foul ecosystems and waterways. The coal yields cheap electricity, but at a high cost in scarred land. Though the scars are upsetting, Hegen says, he gives the portraits an abstract beauty in the hope that people will look at them—and consider the ecological issues they present.

These photographs are of Germany; extraction mining of fossil fuels and minerals creates similar scenes elsewhere. There are signs of change, however. The German government says it will end coal mining and close coal-fueled power plants by 2038. –**DANIEL STONE**

Hegen says some people mistake his images for paintings: "They don't know these places really exist."

For adults with type 2 diabetes (T2D), along with diet and exercise, once-daily RYBELSUS® can help lower blood sugar

Wake Up to the Possibilities of Reaching Your A1C Goal

WAKE UP & RYBELSUS®

RYBELSUS® is proven to lower blood sugar and A1C

In a 6-month study of people with an average starting A1C of 8%, the majority of **people taking RYBELSUS® reached an A1C of less than 7%**[a]:

- Nearly 7 out of 10 people on 7 mg of RYBELSUS®
- Nearly 8 out of 10 people on 14 mg of RYBELSUS®
- About 3 out of 10 people on a sugar pill

RYBELSUS® may help you lose some weight

While not for weight loss, in the same 6-month study, people with an average starting weight of 195 pounds **lost up to 8 pounds**[a]:

- 5 pounds on 7 mg of RYBELSUS®
- 8 pounds on 14 mg of RYBELSUS®
- 3 pounds on a sugar pill

While many people in medical studies lost weight, some did gain weight.

RYBELSUS® does not increase the risk of major cardiovascular (CV) events such as heart attack, stroke, or death[b]

[a] In a 6-month study looking at A1C with 703 adults with T2D comparing 7 mg RYBELSUS® and 14 mg RYBELSUS® with a sugar pill when both were added to diet and exercise.

[b] In a cardiovascular safety study, 3183 adults with T2D and a high risk of CV events were treated with either 14 mg RYBELSUS® or a sugar pill in addition to their usual diabetes and CV medications.

If eligible, **you may pay as little as $10 for a 30-day prescription**[c]

Text[d] **RESULTS to 44535** to learn more about RYBELSUS®

What is Rybelsus®?

Rybelsus® (semaglutide) tablets 7 mg or 14 mg is a prescription medicine for adults with type 2 diabetes that along with diet and exercise may improve blood sugar (glucose).

- Rybelsus® is not recommended as the first choice of medicine for treating diabetes
- It is not known if Rybelsus® can be used in people who have had pancreatitis
- Rybelsus® is not for use in people with type 1 diabetes and people with diabetic ketoacidosis
- It is not known if Rybelsus® is safe and effective for use in children under 18 years of age

Important Safety Information

What is the most important information I should know about Rybelsus®?

Rybelsus® may cause serious side effects, including:

- **Possible thyroid tumors, including cancer.** Tell your healthcare provider if you get a lump or swelling in your neck, hoarseness, trouble swallowing, or shortness of breath. These may be symptoms of thyroid cancer. In studies with rodents, Rybelsus® and medicines that work like Rybelsus® caused thyroid tumors, including thyroid cancer. It is not known if Rybelsus® will cause thyroid tumors or a type of thyroid cancer called medullary thyroid carcinoma (MTC) in people

Do not use Rybelsus® if:

- you or any of your family have ever had MTC, or if you have an endocrine system condition called Multiple Endocrine Neoplasia syndrome type 2 (MEN 2)
- you are allergic to semaglutide or any of the ingredients in Rybelsus®

Before using Rybelsus®, tell your healthcare provider if you have any other medical conditions, including if you:

- have or have had problems with your pancreas or kidneys
- have a history of vision problems related to your diabetes
- are pregnant or plan to become pregnant. It is not known if Rybelsus® will harm your unborn baby. You should stop using Rybelsus® 2 months before you plan to become pregnant. Talk to your healthcare provider about the best way to control your blood sugar if you plan to become pregnant or while you are pregnant
- are breastfeeding or plan to breastfeed. Breastfeeding is not recommended during treatment with Rybelsus®

Tell your healthcare provider about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements. Rybelsus® may affect the way some medicines work and some medicines may affect the way Rybelsus® works.

What are the possible side effects of Rybelsus®?

Rybelsus® may cause serious side effects, including:

- **inflammation of your pancreas (pancreatitis).** Stop using Rybelsus® and call your healthcare provider right away if you have severe pain in your stomach area (abdomen) that will not go away, with or without vomiting. You may feel the pain from your abdomen to your back
- **changes in vision.** Tell your healthcare provider if you have changes in vision during treatment with Rybelsus®
- **low blood sugar (hypoglycemia).** Your risk for getting low blood sugar may be higher if you use Rybelsus® with another medicine that can cause low blood sugar, such as a sulfonylurea or insulin.

  Signs and symptoms of low blood sugar may include: dizziness or lightheadedness, blurred vision, anxiety, irritability or mood changes, sweating, slurred speech, hunger, confusion or drowsiness, shakiness, weakness, headache, fast heartbeat, and feeling jittery
- **kidney problems (kidney failure).** In people who have kidney problems, diarrhea, nausea, and vomiting may cause a loss of fluids (dehydration), which may cause kidney problems to get worse. It is important for you to drink fluids to help reduce your chance of dehydration
- **serious allergic reactions.** Stop using Rybelsus® and get medical help right away, if you have any symptoms of a serious allergic reaction including itching, rash, or difficulty breathing

The most common side effects of Rybelsus® may include nausea, stomach (abdominal) pain, diarrhea, decreased appetite, vomiting, and constipation. Nausea, vomiting, and diarrhea are most common when you first start Rybelsus®.

Please see Brief Summary of Prescribing Information on adjacent page.

[c] Commercially insured patients only. Eligibility and other restrictions apply.

[d] Message and data rates may apply. Check with your mobile service provider. Message frequency will be based on your selections. Text **HELP** to **44535** for help. Text **STOP** to **44535** to quit. See Terms and Conditions of Use at RYBELSUS.com.

See cost and savings info at RYBELSUS.com, and ask your healthcare provider about RYBELSUS® today.

novo nordisk®

RYBELSUS® is a registered trademark of Novo Nordisk A/S.
Novo Nordisk is a registered trademark of Novo Nordisk A/S.
© 2021 Novo Nordisk All rights reserved. US21RYB00042 March 2021

RYBELSUS®
semaglutide tablets 7mg | 14mg

Brief Summary of information about RYBELSUS® (semaglutide) tablets

RYBELSUS®
semaglutide tablets 7mg | 14mg

Rx Only

This information is not comprehensive.

- Talk to your healthcare provider or pharmacist
- Visit www.novo-pi.com/rybelsus.pdf to obtain the FDA-approved product labeling
- Call 1-833-GLP-PILL

Read this Medication Guide before you start using RYBELSUS® and each time you get a refill. There may be new information. This information does not take the place of talking to your healthcare provider about your medical condition or your treatment.

What is the most important information I should know about RYBELSUS®?

RYBELSUS® may cause serious side effects, including:

- **Possible thyroid tumors, including cancer.** Tell your healthcare provider if you get a lump or swelling in your neck, hoarseness, trouble swallowing, or shortness of breath. These may be symptoms of thyroid cancer. In studies with rodents, RYBELSUS® and medicines that work like RYBELSUS® caused thyroid tumors, including thyroid cancer. It is not known if RYBELSUS® will cause thyroid tumors or a type of thyroid cancer called medullary thyroid carcinoma (MTC) in people.
- Do not use RYBELSUS® if you or any of your family have ever had a type of thyroid cancer called medullary thyroid carcinoma (MTC), or if you have an endocrine system condition called Multiple Endocrine Neoplasia syndrome type 2 (MEN 2).

What is RYBELSUS®?

RYBELSUS® is a prescription medicine used along with diet and exercise to improve blood sugar (glucose) in adults with type 2 diabetes.

- RYBELSUS® is not recommended as the first choice of medicine for treating diabetes.
- It is not known if RYBELSUS® can be used in people who have had pancreatitis.
- RYBELSUS® is not for use in patients with type 1 diabetes and people with diabetic ketoacidosis.

It is not known if RYBELSUS® is safe and effective for use in children under 18 years of age.

Do not use RYBELSUS® if:

- you or any of your family have ever had a type of thyroid cancer called medullary thyroid carcinoma (MTC) or if you have an endocrine system condition called Multiple Endocrine Neoplasia syndrome type 2 (MEN 2).
- you are allergic to semaglutide or any of the ingredients in RYBELSUS®.

Before using RYBELSUS®, tell your healthcare provider if you have any other medical conditions, including if you:

- have or have had problems with your pancreas or kidneys.
- have a history of vision problems related to your diabetes.
- are pregnant or plan to become pregnant. It is not known if RYBELSUS® will harm your unborn baby. You should stop using RYBELSUS® 2 months before you plan to become pregnant. Talk to your healthcare provider about the best way to control your blood sugar if you plan to become pregnant or while you are pregnant.
- are breastfeeding or plan to breastfeed. Breastfeeding is not recommended during treatment with RYBELSUS®.

Tell your healthcare provider about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements. RYBELSUS® may affect the way some medicines work and some medicines may affect the way RYBELSUS® works.

Before using RYBELSUS®, talk to your healthcare provider about low blood sugar and how to manage it. Tell your healthcare provider if you are taking other medicines to treat diabetes, including insulin or sulfonylureas.

Know the medicines you take. Keep a list of them to show your healthcare provider and pharmacist when you get a new medicine.

How should I take RYBELSUS®?

- Take RYBELSUS® exactly as your healthcare provider tells you to.
- Take RYBELSUS® by mouth on an empty stomach when you first wake up.
- Take RYBELSUS® with a sip of water (no more than 4 ounces).
- Do not split, crush or chew. Swallow RYBELSUS® whole.
- After 30 minutes, you can eat, drink, or take other oral medications. RYBELSUS® works best if you eat 30 to 60 minutes after taking RYBELSUS®.
- If you miss a dose of RYBELSUS®, skip the missed dose and go back to your regular schedule.
- Talk to your healthcare provider about how to prevent, recognize and manage low blood sugar (hypoglycemia), high blood sugar (hyperglycemia), and problems you have because of your diabetes.

What are the possible side effects of RYBELSUS®?

RYBELSUS® may cause serious side effects, including:

- **See "What is the most important information I should know about RYBELSUS®?"**
- **inflammation of your pancreas (pancreatitis).** Stop using RYBELSUS® and call your healthcare provider right away if you have severe pain in your stomach area (abdomen) that will not go away, with or without vomiting. You may feel the pain from your abdomen to your back.
- **changes in vision.** Tell your healthcare provider if you have changes in vision during treatment with RYBELSUS®.
- **low blood sugar (hypoglycemia).** Your risk for getting low blood sugar may be higher if you use RYBELSUS® with another medicine that can cause low blood sugar, such as a sulfonylurea or insulin. **Signs and symptoms of low blood sugar may include:**
  - dizziness or light-headedness
  - anxiety, irritability, or mood changes
  - slurred speech
  - shakiness
  - fast heartbeat
  - hunger
  - weakness
  - feeling jittery
  - blurred vision
  - sweating
  - confusion or drowsiness
  - headache
- **kidney problems (kidney failure).** In people who have kidney problems, diarrhea, nausea, and vomiting may cause a loss of fluids (dehydration) which may cause kidney problems to get worse. It is important for you to drink fluids to help reduce your chance of dehydration.
- **serious allergic reactions.** Stop using RYBELSUS® and get medical help right away, if you have any symptoms of a serious allergic reaction including itching, rash, or difficulty breathing.

The most common side effects of RYBELSUS® may include nausea, stomach (abdominal) pain, diarrhea, decreased appetite, vomiting and constipation. Nausea, vomiting and diarrhea are most common when you first start RYBELSUS®.

Talk to your healthcare provider about any side effect that bothers you or does not go away. These are not all the possible side effects of RYBELSUS®.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

How should I store RYBELSUS®?

- Store RYBELSUS® at room temperature between 68°F and 77°F (20°C to 25°C).
- Store in a dry place away from moisture.
- Store tablet in the original pack.
- Keep the tablet in the pack until you are ready to take it.
- **Keep RYBELSUS® and all medicines out of the reach of children.**

Revised: 01/2020

Manufactured by: Novo Nordisk A/S, DK-2880
Bagsvaerd, Denmark

RYBELSUS® is a registered trademark of
Novo Nordisk A/S.

© 2020 Novo Nordisk All rights reserved.

US20RYB00618 2/2020

novo nordisk®

IN THIS SECTION
Wandering Rocks
The Iceberg Graveyard
Moving Giraffes by Ark
Yo-Yo Ma's Activism

ILLUMINATING THE MYSTERIES—AND WONDERS—ALL AROUND US EVERY DAY
NATIONAL GEOGRAPHIC
VOL. 239 NO. 5

The Conservation Popularity Contest

WILDLIFE FUNDING AND ADVOCACY FOCUSES HEAVILY ON PROTECTING CHARISMATIC SPECIES. IS IT TIME TO RETHINK THAT APPROACH?

BY **CHRISTINE DELL'AMORE**

TAKE A GOOD LOOK AT the American burying beetle, aka the giant carrion beetle (left). Essentially the vulture of the insect world, this bug once scuttled in droves across 35 states, scouring our fruited plains of all manner of carcasses. Today the beetle is assessed by the International Union for Conservation of Nature as critically endangered. Habitat loss, pesticides, and light pollution may be some of the factors that have left this natural recycler hanging on in only four scattered populations.

Like the tiger, the American burying beetle has orange and black stripes; like the tiger, the beetle is declining in number. The tiger is an instantly recognizable symbol of species preservation, but most people aren't familiar with the beetle.

This discrepancy is an example of the domination of flagship species—the charismatic creatures that nonprofits, government agencies, and other groups use to drum up public interest in conservation. Most

JOEL SARTORE PHOTOGRAPHED THIS AMERICAN BURYING BEETLE AT THE BAYER INSECTARIUM, SAINT LOUIS ZOO, MISSOURI.

Which species could be saved?

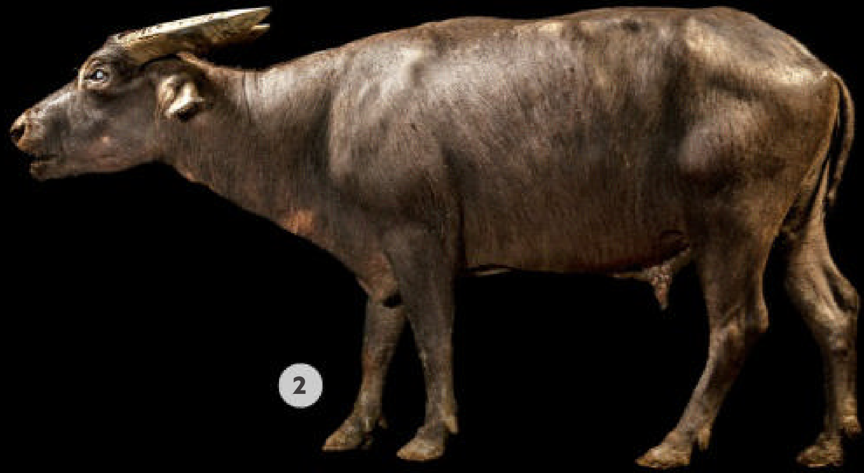
They may not charm us with fuzzy paws and puppy dog eyes, but many less photogenic, oft ignored species deserve some love. The world needs to better recognize the contributions of these underdogs rather than "only spending money on cool species," says conservation scientist Bob Smith. **–CD**

flagships represent just three mammalian orders—primates, predators, and ungulates. That's largely because humans gravitate toward large-bodied animals with forward-facing eyes, humanlike traits that make such species more relatable. As Hugh Possingham, chief scientist for the state of Queensland, Australia, puts it, "It's hard to look into the eyes of a plant."

I've always focused on such shadow species in my work as a wildlife editor and writer—but many don't share my perspective. Most nonprofit funds for animal protection go to the so-called celebrity species, such as apes, elephants, big cats, rhinoceroses, and giant pandas. Tigers are often rated the most popular animal in public surveys—and India, home to the majority of these big cats, spent more than $49 million on tiger conservation alone in 2019.

That's all well and good. Meanwhile, many lesser known species of fish, reptiles, amphibians, and birds languish in anonymity. Take the Philippine crocodile, which is down to about a hundred individuals, or the angel shark, which once ranged throughout European waters and is now extinct in the North Sea. Plants and invertebrates sit even lower on the popularity totem pole; in North America, a freshwater mussel extinction may already be under way. Worldwide, more than 35,500 plant and animal species are on the verge of disappearing forever.

THIS LEAVES US WITH A DILEMMA. Conservation is underfunded—the U.S. Fish and Wildlife Service and other federal agencies sometimes get less than a quarter of the money needed to restore threatened species. The same goes for private philanthropy: In the United States in 2019, just 3 percent of total charitable dollars went to animals and the environment. With a limited pot of money available, how


2

3

4

1. Some people in Madagascar call the **aye-aye,** with its wide-eyed stare and spindly fingers, an evil omen. But the nocturnal primate rids trees of pests, boosting forest health.

2. The critically endangered **Mindoro dwarf buffalo** remains in only one mountainous area of Mindoro island in the Philippines. Scientists say it has flagship species potential because it's unique-looking and rare.

3. A cousin of the Tasmanian tiger, the squirrel-like **numbat** is the only carnivorous marsupial left on Earth. It's extinct in more than 99 percent of its range.

4. North America's largest land bird, with a 9.5-foot wingspan, the **California condor** remains critically endangered. To boost populations, scientists have released captive-bred condors into California, Utah, and Arizona.

Beetle (previous page): Adult American burying beetles feed their babies, an extremely unusual example of parental care among insects.

NATIONAL GEOGRAPHIC
PHOTO ARK
JOEL SARTORE

National Geographic Explorer and photographer Joel Sartore is founder of the National Geographic Photo Ark, a multiyear project using the power of photography to inspire people to help save species at risk before it's too late. The National Geographic Society has supported the Photo Ark since 2012.

do we decide which species to save? The answer, to borrow a phrase, is complicated. It could depend on an animal's likelihood of survival; how it contributes to our economy, as in the case of Atlantic salmon; personal preferences of decision-makers—and, often, politics.

One potential solution, the controversial idea of conservation triage, holds that experts need to quickly decide which species can be saved while realizing that others can't be saved. In the 1980s, when the California condor dwindled to about 22 animals in the wild, debate raged over whether to invest heavily in captive breeding of the species or let it go. Breeding won out, and there are now more than 500 California condors—scavengers that keep their habitats clean—in the wild in California, Utah, Arizona, and northern Mexico. It's generally considered to have been a smart decision.

IN OTHER CASES, making uninformed or ad hoc decisions about conservation can lead to gross misallocation, says Leah Gerber, a conservation scientist at Arizona State University.

The U.S. Fish and Wildlife Service has spent more than four million dollars a year to boost populations of the endangered northern spotted owl, native to the old-growth forests of the Pacific Northwest. But Gerber says it's considered a "costly failure" given that its population is not increasing despite the investment. Texas' threatened bunched cory cactus, on the other hand, gets only about $140,000 a year from the government, yet it could be recovered with an investment of a few tens of thousands more, she says.

That's why Gerber and other conservationists have developed analytic tools to approach the question in a less emotional, more practical way. The U.S.

THESE ANIMALS WERE PHOTOGRAPHED AT DUKE LEMUR CENTER, DURHAM, NORTH CAROLINA (AYE-AYE); TAMARAW GENE POOL FARM, OCCIDENTAL MINDORO, PHILIPPINES (MINDORO DWARF BUFFALO); HEALESVILLE SANCTUARY, VICTORIA, AUSTRALIA (NUMBAT); AND PHOENIX ZOO, ARIZONA (CALIFORNIA CONDOR).

Fish and Wildlife Service now uses this knapsack method—inspired by a hiker’s need to fit the most valuable items into a small space—to get the “most bang for their buck” in saving species, Gerber says. The method’s algorithm calculates the most efficient conservation strategies using factors such as costs to recover a species and its likelihood of going extinct.

Possingham developed a similar model, employed by the Australian and New Zealand governments, called Project Prioritization Protocol. It lessens the pressure and controversy of choosing which species to save by focusing on cost-effectiveness, he says: “It’s exactly how you buy your potatoes, rice, and meat. It really is just common sense.”

Another approach is prioritizing threatened species by their degree of uniqueness. Called EDGE species—for evolutionarily distinct and globally endangered—these are plants and animals that have few close relatives and may single-handedly represent a whole branch of evolutionary history. Losing EDGE species such as Madagascar’s aye-aye, Australia’s numbat, Africa’s shoebill, or the Chinese giant salamander could eliminate a “storehouse of benefits in the tree of life that we haven’t explored,” says Nisha Owen of the U.K. nonprofit On the EDGE Conservation. For example, the critically endangered axolotl, a salamander native to Mexico, has regenerative properties that could advance human medicine, she says.

In Owen’s view, the triage conservation model asks what we’re going to let go, while the EDGE model more optimistically asks what we’re going to focus on. The EDGE model assigns scores to species based on evolutionary distinctiveness and global endangerment and prioritizes those with the highest scores. Today, Owen says, 90 of the hundred highest priority species need more conservation attention.

SOME ARGUE THAT CONSERVATION should focus on whole ecosystems instead of single species. Others espouse what’s called the umbrella method—the notion that by living in a celebrity species’ habitat, smaller creatures will be protected as well.

The thing is, that only works in some situations. Take the beloved giant panda. In putting so much effort into its national icon, China has at least partially protected many of its native forest birds and mammals in the panda’s habitat, such as the Lady Amherst’s pheasant and the endangered golden snub-nosed monkey, says Duke University conservationist Stuart Pimm.

On the other hand, the endangered purple frog, found only in the Bengal tiger’s range of India’s Western Ghats, has not benefited from massive investments in the tiger’s habitat, Owen says. That’s because what the purple frog needs to thrive—land with fast-flowing streams and largely free of roads—is different from what the tiger needs.

Pimm also offers this caution: that even carefully crafted, supposedly rational conservation methods may have flaws—and may provide “an excuse not to make tough decisions about conservation.” Leaning on data alone, he argues, could give government agencies the all clear to let species go extinct or even provide a scientific rationale for a political decision.

I SUSPECT THAT MOST OF US who care about animals could agree on this: Charisma is in the eye of the beholder. In that case, can’t we broaden the list of animals considered appealing and even beautiful? University of Kent conservationist Bob Smith says we can—and there’s a name for them: Cinderella species. These are mostly threatened animals that, based on internet searches, are still very popular with the public yet are typically overlooked as flagships. Think Mindoro dwarf buffalo, African wild ass, pygmy raccoon—and there are many more. Smith is convinced that “less well known and less appealing species can still be good flagships with more marketing effort.”

In a recent study, Smith laid to rest another myth about poster animals: that they don’t help publicize the world’s most species-rich and threatened places. A prioritization model Smith created showed that the most important conservation hot spots worldwide also are home to more than 500 flagship and Cinderella mammals, birds, and reptiles—and that drawing more attention to these animals could boost funding and public campaigns for habitat protection.

Let’s be clear, though: It’s still OK to root for pandas and tigers. “The reason I got into conservation is because I liked these species,” Smith says. “That is fair enough. But it’s our job as conservationists to try to inspire people to love other species too.”

Christine Dell’Amore, a veteran *National Geographic* editor and writer, covers wildlife and is a self-described fan of underloved and little-appreciated animals.

Hummingbirds and habitats

To inform British Columbia’s conservation efforts, wildlife ecologist Adam Ford created a model showing which of a thousand Canadian species overlap the most in province habitats. A top surrogate species—so named because it’s representative of other species that thrive in a given area—surprised them: the rufous hummingbird, a feathered dynamo just three inches long. “If you conserved habitat of the rufous hummingbird, we would have the greatest impact on the species in British Columbia,” Ford says. “Could you build a conservation program with hummingbirds? I don’t know. But it tells us that people who elevate charismatic megafauna ought to consider the utility of these other species.” **—CD**

PHOTO: ANAND VARMA

CLOSE ENCOUNTERS OF
THE WILD KIND

From Alaska to Antarctica, traveling on a National Geographic Expedition brings you closer to some of the planet's most spectacular coastal wilderness where whales and wildlife thrive. When you travel with us, you will be joined by National Geographic Experts and naturalists and you'll explore in ways you never thought possible, enjoying in-depth insights from the people who have devoted their lives to studying the species you encounter. When you're ready, we can't wait to explore with you.

NATIONAL GEOGRAPHIC
EXPEDITIONS

NATGEOEXPEDITIONS.COM | 1-888-351-3274

© 2021 National Geographic Partners, LLC. National Geographic EXPEDITIONS and the Yellow Border Design are trademarks of the National Geographic Society, used under license.

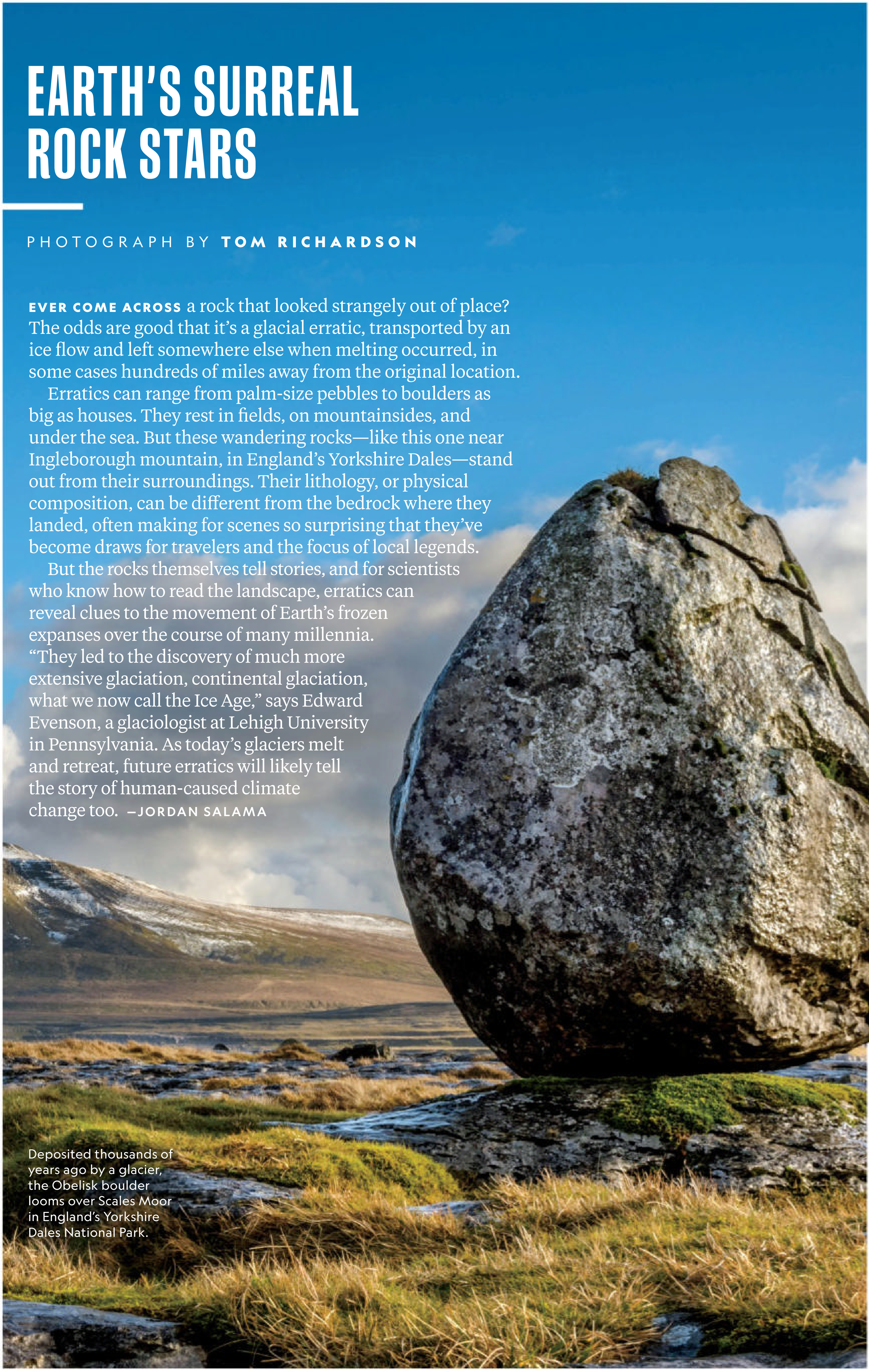
EARTH'S SURREAL ROCK STARS

PHOTOGRAPH BY **TOM RICHARDSON**

EVER COME ACROSS a rock that looked strangely out of place? The odds are good that it's a glacial erratic, transported by an ice flow and left somewhere else when melting occurred, in some cases hundreds of miles away from the original location.

Erratics can range from palm-size pebbles to boulders as big as houses. They rest in fields, on mountainsides, and under the sea. But these wandering rocks—like this one near Ingleborough mountain, in England's Yorkshire Dales—stand out from their surroundings. Their lithology, or physical composition, can be different from the bedrock where they landed, often making for scenes so surprising that they've become draws for travelers and the focus of local legends.

But the rocks themselves tell stories, and for scientists who know how to read the landscape, erratics can reveal clues to the movement of Earth's frozen expanses over the course of many millennia. "They led to the discovery of much more extensive glaciation, continental glaciation, what we now call the Ice Age," says Edward Evenson, a glaciologist at Lehigh University in Pennsylvania. As today's glaciers melt and retreat, future erratics will likely tell the story of human-caused climate change too. —JORDAN SALAMA



Deposited thousands of years ago by a glacier, the Obelisk boulder looms over Scales Moor in England's Yorkshire Dales National Park.

LITTLE PACKAGE, LOTS OF FLAVOR—
just like me!
Try our NEW PATÉ recipes
PURINA
Beneful
IncrediBites
just for small dogs
3 3oz CANS
NO ARTIFICIAL PRESERVATIVES, COLORS, OR FLAVORS
with real beef, tomatoes, carrots & wild rice
paté just for small dogs

BENEFUL INCREDIBITES WET RECIPES

Great flavor and nutrition all in one package.

- Made with delicious real beef, chicken or salmon
- No artificial flavors, colors or preservatives
- High-protein recipes specially formulated for small dogs

Learn more at Beneful.com/IncrediBites

HEALTHFUL.
FLAVORFUL.
PURINA®
Beneful®

Purina trademarks are owned by Société des Produits Nestlé S.A.

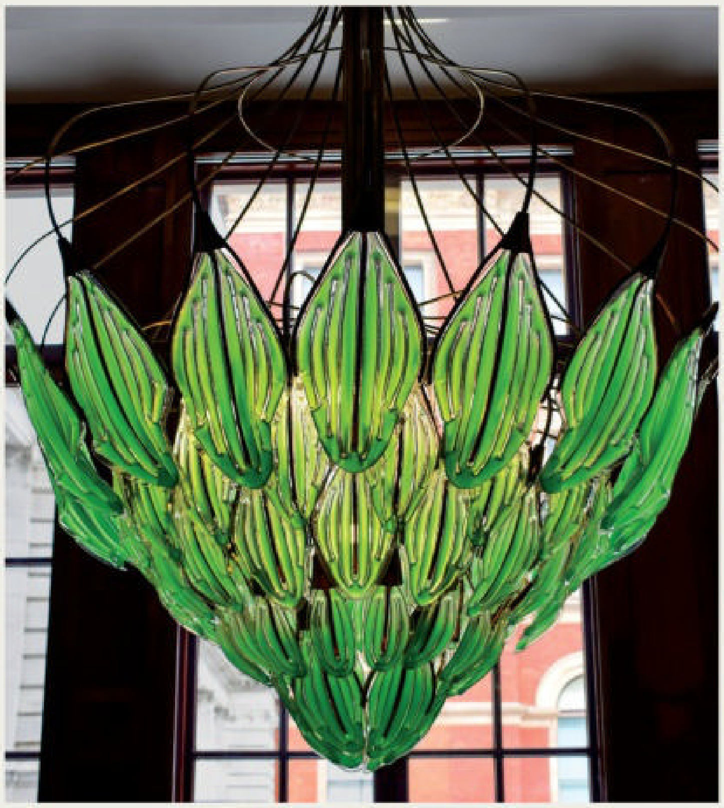
PURINA® Your Pet, Our Passion.®

PLANET
POSSIBLE

For more stories about how to help the planet, go to *natgeo.com/planet*.

Pollution That Looks Good on Paper

Your printer cartridges and air pollution have something in common: carbon. The black particles emitted from burning fossil fuels make good pigment. That's why a start-up in India makes Air-Ink, turning exhaust harvested from diesel generators into ink for uses from art to packaging. Computer giant Dell is eyeing the sooty brew for printing its product boxes. —CHRISTINA NUNEZ



ECO-TECHNOLOGY

HOW ART CLEARS THE AIR

THIS CHANDELIER DOESN'T JUST SHED LIGHT; IT TAKES IN CARBON DIOXIDE AND RELEASES OXYGEN.

IN THE ECLECTIC COLLECTION of the Victoria and Albert, the museum of art and design in London, only one object—out of more than 2.3 million—is alive: a chandelier (above). The fixture not only provides light but also absorbs light and purifies the air in the room. Hanging from the chandelier's metal branches are 70 veined, synthetic pouches, "leaves" made green by the millions of algal microorganisms inside. The algae take in light from LEDs and the sun, and carbon dioxide from the air; when that mixes with water and nutrients circulating in the leaves, oxygen is produced. In short: This chandelier performs photosynthesis. When museumgoers visit the artwork, titled "Exhale," breathing becomes a reciprocal activity: They breathe out CO_2, which the algae replace with oxygen.

"Exhale" was devised by engineer-inventor Julian Melchiorri and his company, Arborea. The start-up is developing technologies to industrialize photosynthesis for use in a sustainable food system, as well as to fight climate change and pollution. Melchiorri says algae work so well in these applications that they soon could be in wider use: in "biosolar" panels on buildings' rooftops, and even in spaceships and space colonies. —HICKS WOGAN

ECO-DESIGN

Green Grow His Towers

Plant-covered edifices have sprouted worldwide since Italian architect Stefano Boeri created the Bosco Verticale, or Vertical Forest, in Milan in 2014. Two residential towers wrapped in 800 trees and 5,000 shrubs, the Bosco (below) thrilled tenants and critics alike with its luxuriant aesthetic, sun-shielding facade, and eco-friendliness. The project has been emulated from Amsterdam to Shanghai. Boeri is designing green towers on several continents and a green vertical city near Cancún, Mexico. —SAM LUBELL

PHOTOS (FROM TOP): GRAVIKY LABS; JULIAN MELCHIORRI; DIMITAR HARIZANOV, BOERI STUDIO

PURINA

"Their Future Good Health Starts Today."

DR. ANNIE VALUSKA

Purina puppy and kitten food is formulated to meet your pet's needs now, and set the stage for a lifetime of good health. Because we care about what you care about—nutrition that helps our pets thrive today and tomorrow.

- **High Protein for Muscle Development**
- **DHA for Vision & Brain**
- **Antioxidants to Support Immune Health**

Learn more at **PURINA.COM/HEALTHY-START**

Scan to buy now.

PURINA TRADEMARKS ARE OWNED BY SOCIÉTÉ DES PRODUITS NESTLÉ S.A.

PURINA Your Pet, Our Passion.

PLANET
POSSIBLE

For more stories about how to help the planet, go to *natgeo.com/planet*.

Every day we find new ways to conserve Earth's resources. Here are five.

BY **CHRISTINA NUNEZ**

1

FROM YOUR CLOSET

Your Cast-Off Blue Jeans Could Become Home Insulation

Those beloved jeans served you well. When it's time to let go, don't trash them. More than 11 million tons of textiles went to U.S. landfills in 2018—nearly 8 percent of all waste. Now retailers such as Levi's and Madewell are collecting used denim to be turned into building insulation you can buy at home improvement stores. Find information on donating denim at *bluejeansgogreen.org*.

2

ON THE ROAD

WOULD YOU GET AN ALTERNATIVE-FUEL OR HYBRID VEHICLE IF IT BESTED YOUR CAR IN EMISSIONS, COST, AND PERFORMANCE? SEE HOW VEHICLES COMPARE, USING THE U.S. ENERGY DEPARTMENT'S ONLINE CALCULATOR: *AFDC.ENERGY.GOV/CALC.*

3

IN YOUR KITCHEN

Pop the Cork—and Donate It

When you recycle wine bottles, don't forget the stoppers. ReCork has collected over 110 million natural corks for reuse as shoe soles and other items. ***recork.com***

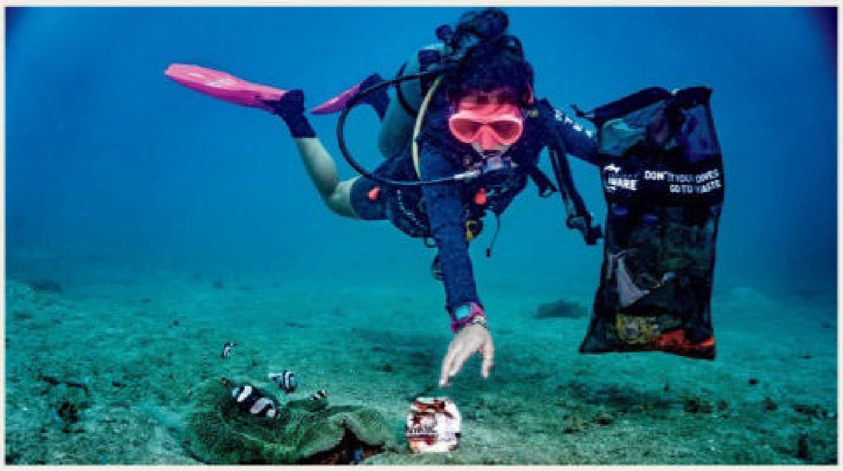
4

AS YOU SHOP

REUSE THE CONTAINERS

Is guilt-free Häagen-Dazs possible? Wastewise, maybe. Online store Loop sells the ice-cream brand and other staples in packaging you can send back for refills. *loopstore.com*

5



IN THE OCEAN

If you dive, join over 90,000 others worldwide who have picked up more than 1.8 million pieces of marine trash—so far. Learn more about this "dive against debris" initiative at *projectaware.org*.

PHOTOS (CLOCKWISE FROM TOP LEFT): JIM WATSON, AFP VIA GETTY IMAGES; REBECCA HALE, NGM STAFF; LOOP; CHARLIE FENWICK

Establishing a **charitable gift annuity** with the National Geographic Society is a great way to receive guarenteed payments for life and save on taxes—while protecting our planet for generations to come.

COPYRIGHT 2021 NATIONAL GEOGRAPHIC SOCIETY
PHOTO COURTESY OF EDSON VANDEIRA

SIMPLE + SAFE. SECURE YOUR FUTURE WITH LIFETIME PAYMENTS.

☐ Yes! I am interested in a charitable gift annuity. Please send me a custom illustration of my estimated payout rate, payment, and tax savings.

Gift Amount: $ ____________________
(Minimum gift is $10,000)

Please indicate birthdates for up to two beneficiaries: ____________________
(Minimum age is 60)

☐ I have some questions. Please call me.

Mail to: National Geographic Society
Office of Gift Planning
1145 17th Street, N.W.
Washington, D.C. 20036-4688

Contact: legacy@ngs.org
(800) 226-4438
natgeo.org/give/future-gifts

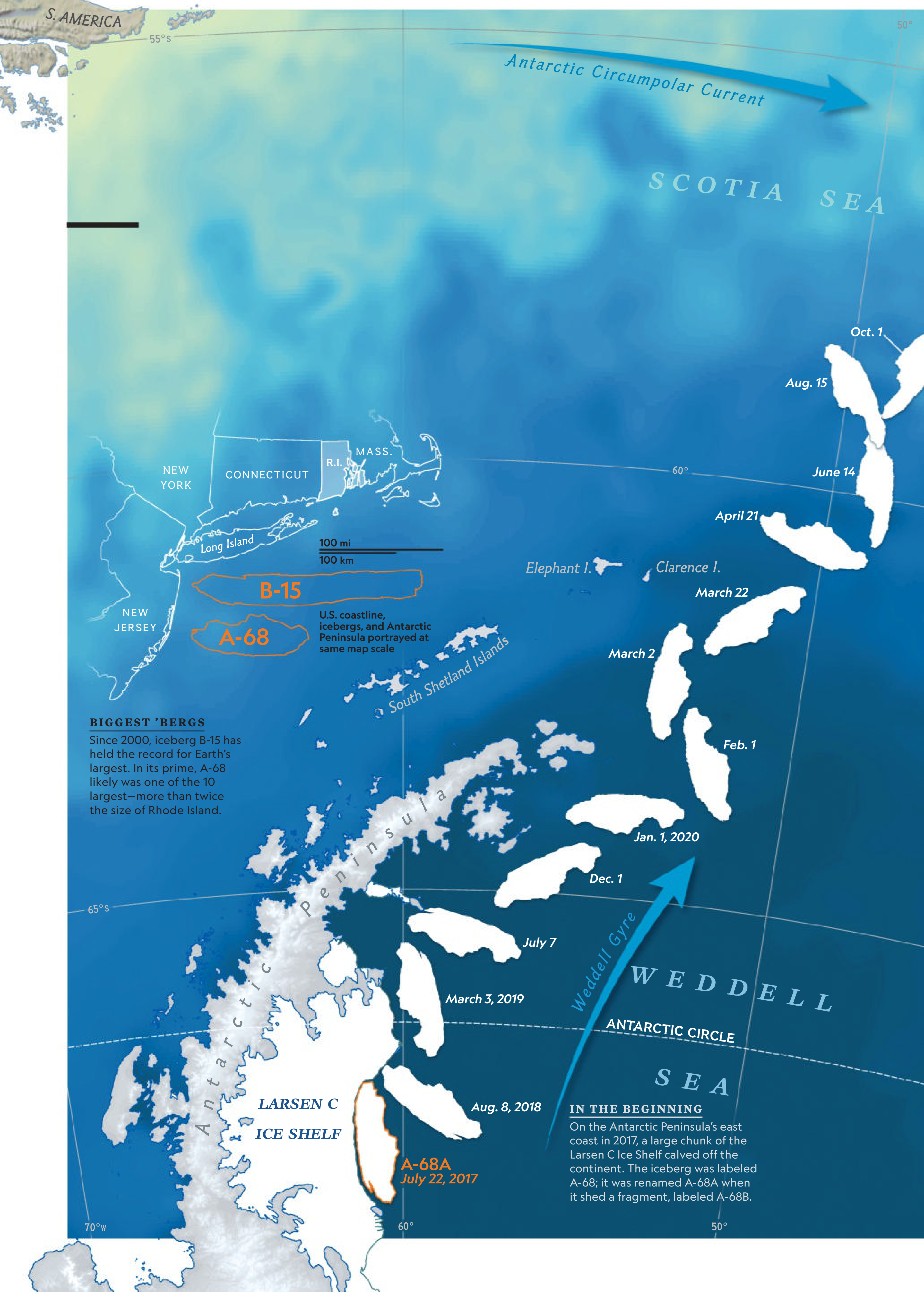
NAME

ADDRESS

PHONE EMAIL

The National Geographic Society is a 501(c)(3) non-profit organization. Our federal tax ID number is 53-0193519.

21PGAD05



BIGGEST 'BERGS

Since 2000, iceberg B-15 has held the record for Earth's largest. In its prime, A-68 likely was one of the 10 largest—more than twice the size of Rhode Island.

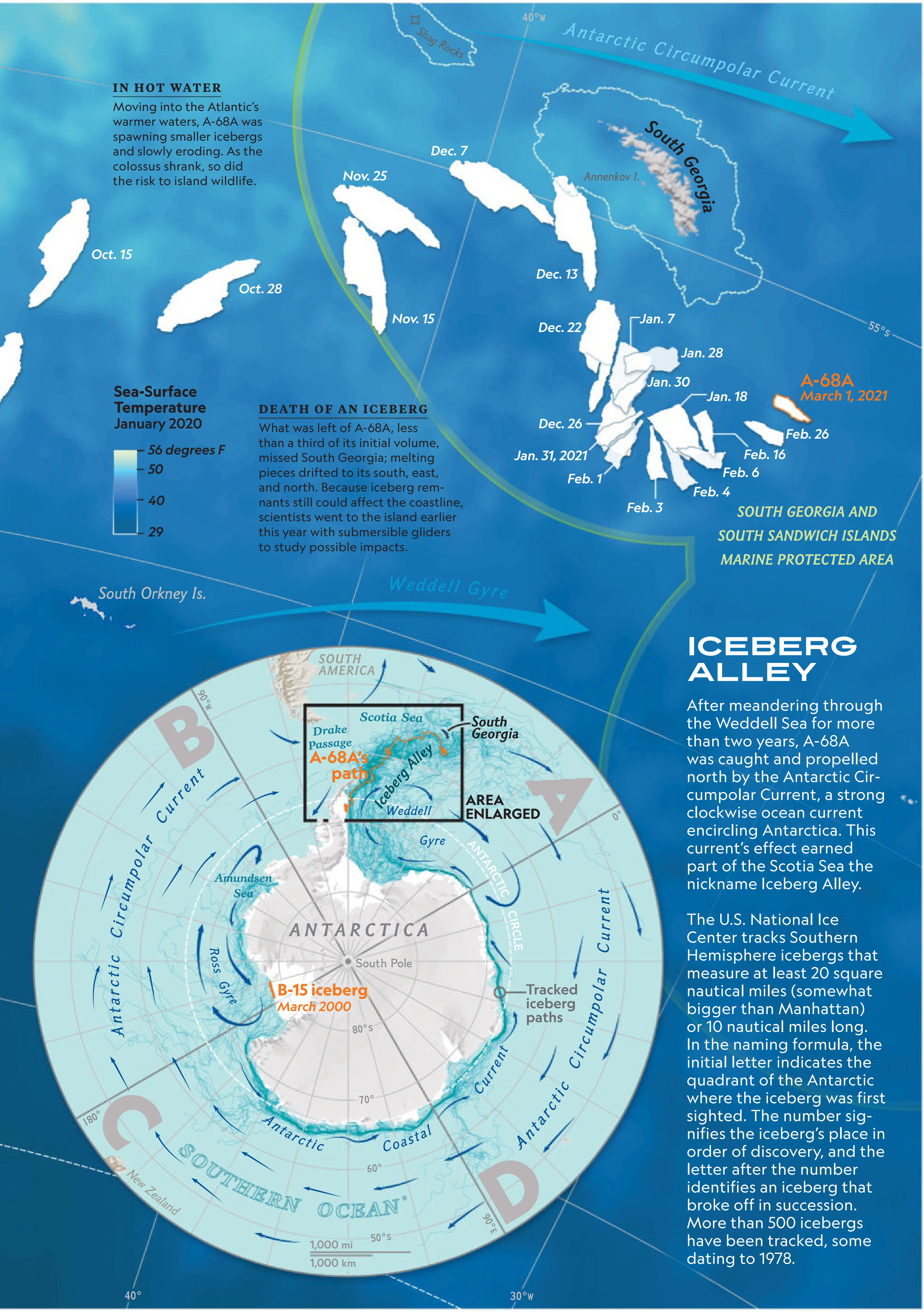
IN THE BEGINNING

On the Antarctic Peninsula's east coast in 2017, a large chunk of the Larsen C Ice Shelf calved off the continent. The iceberg was labeled A-68; it was renamed A-68A when it shed a fragment, labeled A-68B.

ICEBERG ALLEY

After meandering through the Weddell Sea for more than two years, A-68A was caught and propelled north by the Antarctic Circumpolar Current, a strong clockwise ocean current encircling Antarctica. This current's effect earned part of the Scotia Sea the nickname Iceberg Alley.

The U.S. National Ice Center tracks Southern Hemisphere icebergs that measure at least 20 square nautical miles (somewhat bigger than Manhattan) or 10 nautical miles long. In the naming formula, the initial letter indicates the quadrant of the Antarctic where the iceberg was first sighted. The number signifies the iceberg's place in order of discovery, and the letter after the number identifies an iceberg that broke off in succession. More than 500 icebergs have been tracked, some dating to 1978.



IN HOT WATER

Moving into the Atlantic's warmer waters, A-68A was spawning smaller icebergs and slowly eroding. As the colossus shrank, so did the risk to island wildlife.

DEATH OF AN ICEBERG

What was left of A-68A, less than a third of its initial volume, missed South Georgia; melting pieces drifted to its south, east, and north. Because iceberg remnants still could affect the coastline, scientists went to the island earlier this year with submersible gliders to study possible impacts.

Fleeing the Flood

RISING WATER THREATENED THE RARE GIRAFFES' HOME IN KENYA. SO FORMER ENEMIES JOINED FORCES TO RELOCATE THE GIANT ANIMALS, USING A MODERN-DAY ARK.

BY **ANNIE ROTH**
PHOTOGRAPHS BY **AMI VITALE**

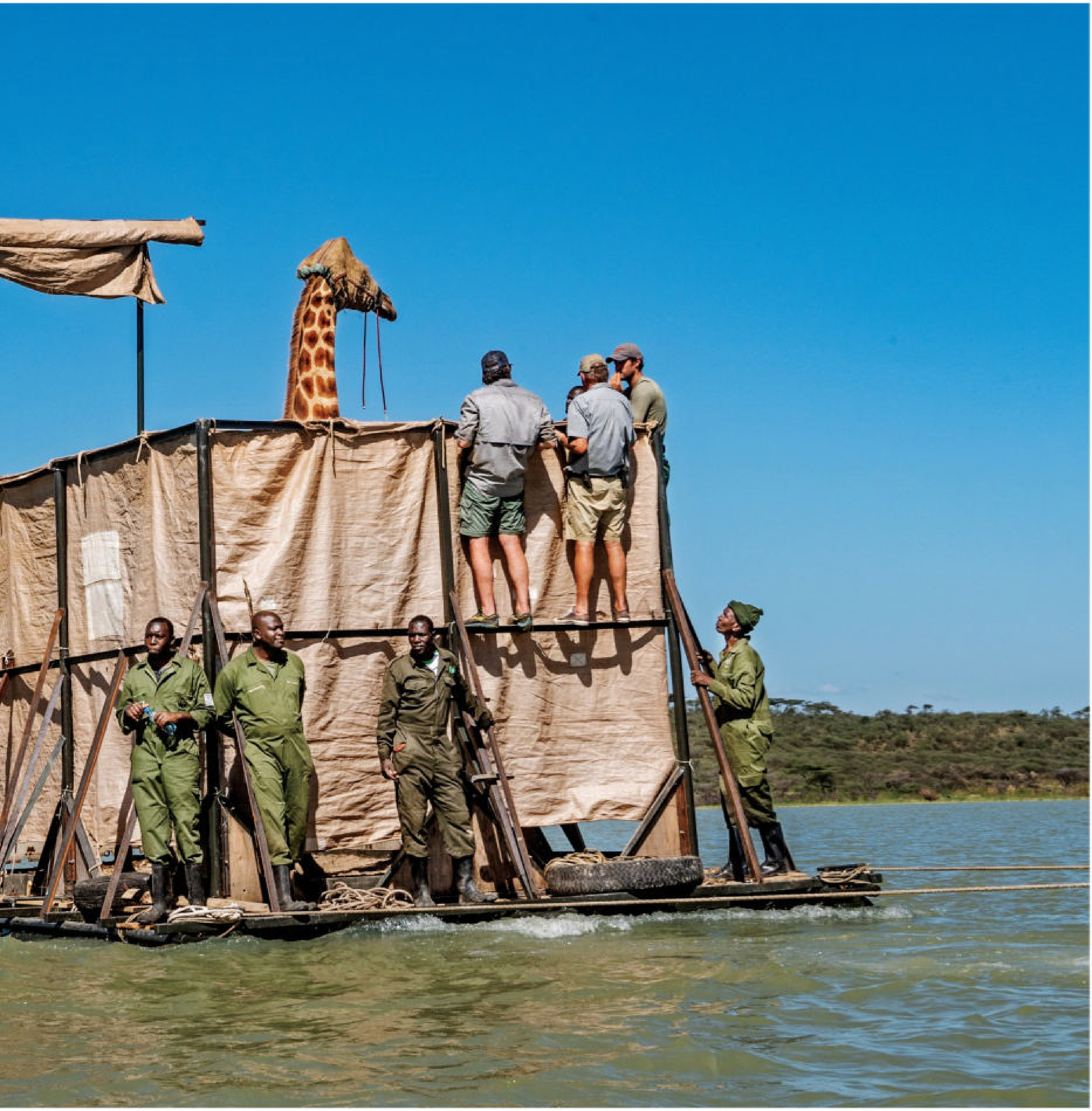
THERE WAS A TIME, not long ago, when peace between the Pokot and the Ilchamus seemed impossible. Living along the shores of Kenya's Lake Baringo, the two communities had spent decades waging war over cattle, land, and water—turning one of Kenya's most biodiverse regions into a barren battlefield.

In 2006 Pokot and Ilchamus elders reached a truce in their bitter conflict. They agreed that to build unity and trust, the former enemies would work together to bring back the wildlife that their conflict helped drive out—starting with the Rothschild's giraffe.

These giraffes' numbers are dwindling. Only around 2,000 remain in the wild, and 800 of those live in Kenya. The Rothschild's giraffe, also known as the Baringo giraffe, was once abundant around Lake Baringo, but the iconic breed went extinct in the area after decades of conflict and poaching.

Eager to see these giraffes return to their homeland, Pokot and Ilchamus community members got to work. Within a year they had established the Ruko Conservancy, a 44,000-acre community conservancy where both the Pokot and Ilchamus work. "It wasn't easy," says Rebby Sebei, a Pokot community member who manages the conservancy. "But both sides were keen for change."

In 2011 the conservancy received its first group of Rothschild's giraffes: eight animals relocated from other areas in hopes that they'd multiply and repopulate the area. The giraffes were placed on a peninsula in Lake Baringo, where they could be easily protected from poachers.



The species' return to Lake Baringo attracted tourists, giving the local economy a much needed boost. The relocated animals, and their offspring born on the peninsula, became "a symbol of peace, unity, and a source of community wealth," Sebei says.

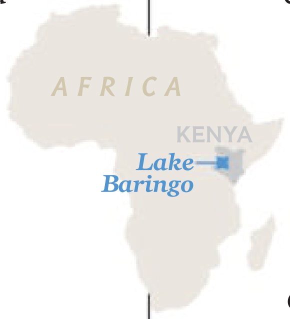
After years of harmony, disaster struck. Heavy rains fell, flooding many parts of Kenya's Rift Valley, including Lake Baringo. By 2020 the lake's rising waters had displaced more than 5,000 people and destroyed schools, hospitals, and homes.

The flooding turned the giraffes' 100-acre peninsula into a rapidly shrinking island. They were trapped without enough food, even when rangers brought some from the mainland. Several animals, adults and calves, died as the waters crept higher.

Already contending with a global pandemic and a natural disaster, the Pokot and Ilchamus communities set out to rescue the eight giraffes that remained. After weighing all options, the best idea—though still difficult and dangerous—seemed to be to load each giraffe onto a barge that a boat would tow to the mainland.

Getting a wild animal that stands upwards of 18 feet tall, and can weigh nearly as much as a compact car, onto a barge safely is no easy task. "From the onset, I knew the work would be both challenging and delicate," said Stephen Chege, a senior wildlife veterinarian working with the Northern Rangelands Trust, one of several groups that joined the effort. Giraffes don't handle tranquilizers well—sedated giraffes have been known to choke on their own saliva—and their unique physiology makes them prone to neck and leg injuries. Chege and the other rescuers had their work cut out for them.

Using metal drums, steel beams, and tarps, Pokot and Ilchamus community members built a barge that was sturdy enough to transport the giraffes across the lake. They also set up a 4,400-acre, predator-proof sanctuary on the mainland, where the giraffes could acclimate to their new surroundings.



The first giraffe slated for rescue was a female named Asiwa. She had spent most of 2020 alone after rising water bisected the island, isolating her from the rest of her herd. Rescuers hoped they could lure her onto the barge using mangoes and other tasty treats—but when they tried, Asiwa appeared uninterested. "She was quite skittish," says David O'Connor, president of the nonprofit group Save Giraffes Now. "She didn't know we were trying to help her."

The rescuers decided to tranquilize Asiwa and outfit her with a blindfold and harness, which would allow them to guide her onto the barge. The plan was risky: If Asiwa fell into the water, she would almost certainly drown. When the tranquilizer dart hit, Asiwa took off running in the opposite direction of the barge—but keeled over "about a foot from the water," says O'Connor. "We were incredibly lucky." Once Asiwa was down, the rescuers rushed in, injecting a tranquilizer-reversal drug, stuffing socks into her ears, blindfolding her, and equipping her with a makeshift harness. When Asiwa rose to her feet, you could hear a pin drop. "Everyone was really nervous," O'Connor says.

Through the island's harsh terrain, the rescuers guided Asiwa across the island and onto the barge. It was slow going at first, but once she hit her stride, "it looked like someone walking a dog on a Sunday afternoon in the park," O'Connor says. When they reached the barge, Asiwa walked right on, and relieved rescuers shut the gate behind her.

O'Connor described her as "totally calm" during her hour-long voyage to the mainland, where a crowd of Pokot and Ilchamus people waited.

When the barge reached the shore, the rescuers removed the earplugs, harness, and blindfold, and let Asiwa loose. As she stepped off the barge and onto the sanctuary ground, the crowd burst into applause. "It was a dream that came true," says Sebei. "Happiness engulfed everyone."

Around Christmas, a giraffe calf was born on the island and was named Noelle. After Asiwa, two more giraffes were rescued: Pasaka, a female, had to be sedated—but Lbarnoti, a male, was lured onto the barge with food. In the next few months the rescuers expected to move the last of the giraffes off the island, to their new home on the mainland.

The task is daunting—but "where there is peace," Sebei says, "everything is possible." □

Annie Roth, a California-based science journalist, enjoys writing about endangered species and the people who study them.

After evacuation from land that was flooding, the Rothschild's giraffes will live in a 44,000-acre wildlife conservancy.

HOW YOU CAN HELP

Save Giraffes Now supports immediate, on-the-ground conservation in Africa, from rescues to relocations. Donate here: *savegiraffesnow.org/donate.*

Tell a friend. Many people don't know giraffes are in trouble—but their numbers dropped by roughly 40 percent in just 30 years (1985-2015).

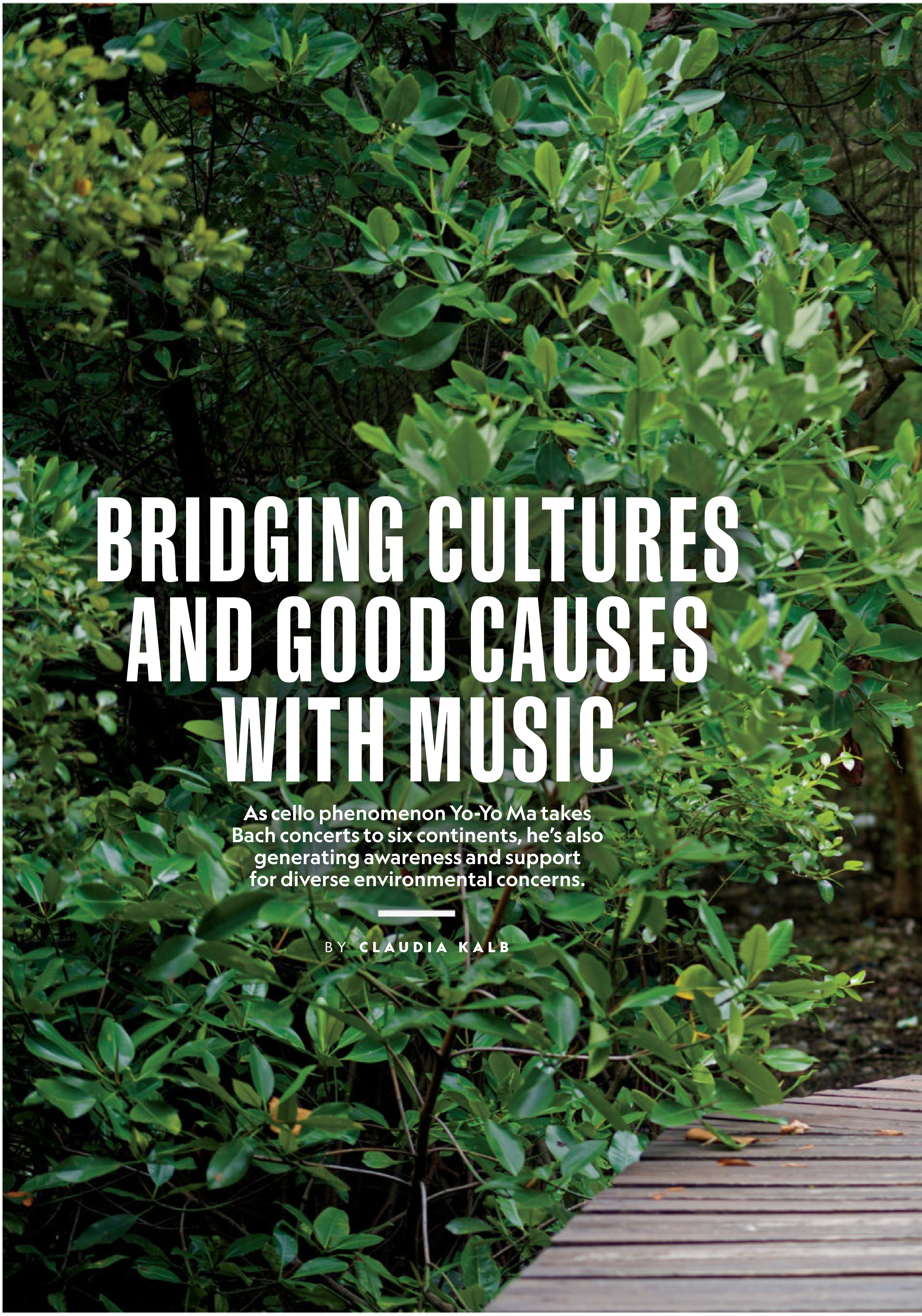
NGM MAPS

THE SKY WAS THE LIMIT.

INTRODUCING THE ALL-NEW

PANGA® 22" WATERPROOF LUGGAGE.

YETI® BAGS



BRIDGING CULTURES AND GOOD CAUSES WITH MUSIC

As cello phenomenon Yo-Yo Ma takes Bach concerts to six continents, he's also generating awareness and support for diverse environmental concerns.

BY **CLAUDIA KALB**

In Jakarta, Indonesia, in 2019, Yo-Yo Ma plays a "Music in the Mangroves" concert, to help scientists and community members drive home the importance of saving threatened mangrove ecosystems.

PHOTO: AUSTIN MANN

ON A SUNLIT FEBRUARY morning in Cape Town, Ross Frylinck waited near the doorway of a private home perched on a steep mountainside overlooking False Bay. Co-founder of the Sea Change Project, an environmental organization dedicated to preserving the kelp forest in South Africa's coastal waters, Frylinck had gathered with a group of colleagues and musicians to welcome Yo-Yo Ma to Cape Town, one of 36 stops on the cellist's six-continent tour known as the Bach Project.

Preparing to receive one of the world's most celebrated musicians caused some trepidation. "We were all a bit intimidated," Frylinck said later. But the tension dissipated as soon as Ma arrived. The cellist's face was open and warm, and his demeanor caring, earnest, and inquisitive. "His whole heart was smiling in the room," Frylinck said.

Inside the small wood and stone dwelling, Frylinck and Sea Change co-founder Craig Foster told Ma about their campaign to protect what they call the Great African Seaforest, a swaying jungle of giant kelp that Frylinck likens to an untouched Amazon rainforest, with dense canopies of plants and flocks of fish that fly like birds through the currents. The activists showed Ma the percussion and other musical instruments that their team created from materials that washed up on the beach on Cape Town's coast: shakers made from shark egg cases, a stringed instrument made from abalone shell, a drum made from a humpback whale ear bone. And they introduced Ma to South African singer Zolani Mahola, who had helped the group bring together instruments, music, and lyrics to fashion their sea-forest anthem.

As Ma listened, Mahola and a group of Sea Change musicians and collaborators staged their first performance of "My Amphibious Soul," the melodic narrative they had culled and shaped from the waters. Ma was transfixed by the sounds, new to his ear, and the players' inventiveness. "They made what we couldn't see, feel, and hear—they made it visible and audible and tactile," he told me later. The composition gave the Great African Seaforest a voice, and an enthusiastic devotee in Ma.

Then it was the cellist's turn. He took a seat outdoors, on a mountainside deck trimmed with driftwood. As whitecaps danced atop waves below and Cape Town's mountains stood tall on the horizon, Ma played one of Johann Sebastian Bach's six *Suites for Unaccompanied Cello.* The setting and the eloquence of Ma's performance stirred his listeners. So did the essence of the musician—an exuberance that turns horsehair and wood into rapture.

Frylinck told me later that in the course of his lifetime, he had encountered only two other people who struck him as Ma did: a monk at a temple in Japan and legendary leader Nelson Mandela. "For me, Yo-Yo Ma had that quality of basic goodness," Frylinck said. "I just had this feeling that this man is a bodhisattva"—a compassionate figure who helps others attain enlightenment.

Ma clearly is a man of action. Before leaving Cape Town, he agreed to become a patron of the Sea Change Project. Months later, he posted about his visit on social media, created a video in support of Sea Change's work, and when interviewed, made a point of talking about the need to protect the kelp forest. Last fall the cellist invited Mahola and Sea Change musicians to join him in a virtual concert celebrating the 75th anniversary of the creation of the United Nations. Ma, a UN Messenger of Peace, featured "My Amphibious Soul" in his repertoire, along with works by Antonín Dvořák and Ludwig van Beethoven.

Since the intimate gathering with Ma in Cape Town, the Sea Change Project has been elevated from local advocacy circles onto the global stage. "It was a total wake-up moment for me personally, because our mission is to win hearts and minds for the benefit of the ocean," Frylinck says. "How do you do that? You connect with people who already have won hearts and minds and are naturally aligned with your conservation work and want to do good and be part of it." Ma's patronage, he adds, was the missing link that Sea Change needed. "It opened so many doors that would never otherwise be opened."

YO-YO MA'S CAREER highlights are staggering. A child prodigy who performed for President John F. Kennedy at the age of seven, the cellist has since recorded more than 100 albums, received 18 Grammy Awards, and played for nine U.S. presidents. Yet at 65, Ma remains a self-deprecating, tireless, and purposefully optimistic human being who shares his music as a means of connecting with people and the world.

Ma believes that culture—which he defines broadly as the place where the arts, sciences, and society converge—can help assuage discord, strengthen community bonds, promote social justice, and protect the planet. In 2018 the cellist embarked on the Bach

Project, an ambitious journey that uses culture as a bridge to connect with communities, launch conversations, and spotlight efforts that strive to do good.

So far, Ma has been to 28 of the tour's 36 destinations—places as far-flung as Mumbai, India; Mexico City, Mexico; Dakar, Senegal; and Christchurch, New Zealand. The anchor of the project is Bach's six cello suites, which Ma plays from memory in concerts that last more than two hours, with no intermission. Performances are paired with Days of Action, where Ma helps raise awareness about issues of local and global importance during events with community leaders, citizens, artists, students, and activists. For example, in Chicago Ma confronted gun violence by joining a tree planting—using shovels that were made from donated weapons. In Korea the cellist visited an elementary school in the Demilitarized Zone with a traditional kitemaker, giving students, villagers, and teachers the opportunity to decorate kites with their aspirations for the future.

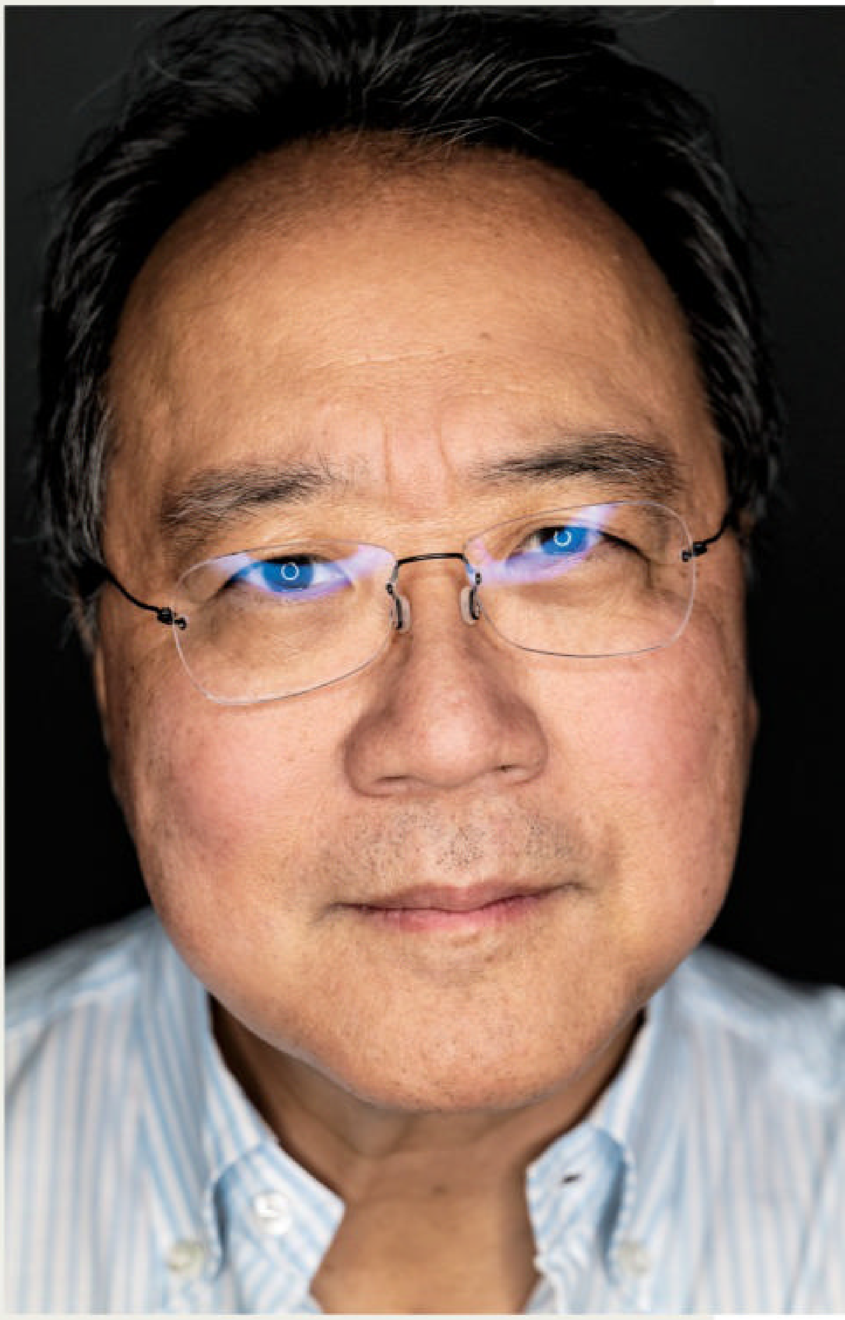
At every event and stop, Ma's mission is the same: to listen, discover, and join with others to build a better future.

BORN IN PARIS to Chinese parents, Ma began playing the cello at the age of four (at first, he sat on three phone books because no chair was low enough). He spent his early childhood in France before his family immigrated to New York City the year he turned seven. This mélange of cultural forces—Chinese, French, American—confused him but also fueled an early and fervent curiosity about the world.

Ma's professional career took off when he was in his teens. He made his solo debut at Carnegie Hall in May 1971 at the age of 15, followed by performances that earned accolades from the critics: "electrifying," "staggering," "stunning." But rather than continue his studies at Juilliard—a natural choice for a player of his talent—Ma enrolled at Harvard. There he discovered a passion for anthropology and mingled with classmates who came from diverse cultures and had different interests: "That dovetailed well with the burgeoning career of a young musician trying to make his way in the world," he says now.

Those interactions shaped Ma's perception of music as a shared experience that gives him access to knowledge. He is perpetually hungry for it; that's clear in the way he stops and chats with strangers at events, asking questions of everyone, even as his staff members gently tug at him to move on. Ma seeks insights; he wants to know. When he was in his late 30s, Ma went to Africa to study the musical traditions of the Kalahari bushmen. That visit illuminated a fundamental truth about music: It's organic, a living thing that can evolve at any place at any time.

Collaborations are Ma's hallmark. He released the highly successful album *Hush* with vocalist Bobby McFerrin in the early 1990s. He launched the Silkroad Ensemble in 2000, bringing together musicians of dozens of nationalities, including Galician bagpiper



MA BELIEVES THAT CULTURE—WHICH HE DEFINES BROADLY AS THE PLACE WHERE THE ARTS, SCIENCES, AND SOCIETY CONVERGE—CAN HELP ASSUAGE DISCORD, STRENGTHEN COMMUNITY BONDS, PROMOTE SOCIAL JUSTICE, AND PROTECT THE PLANET.

PHOTO: MARK MANN

Cristina Pato. One evening at New York University, I heard Ma and Pato play an exquisite Bach saraband, merging two instruments that don't often meet, but should. Last year Ma released a new album, *Not Our First Goat Rodeo,* with Americana musicians Edgar Meyer on bass, Chris Thile on mandolin, and Stuart Duncan on violin.

Ma likens these cross-cultural alliances to the "edge effect" in ecology, which occurs at the border where two different habitats intersect, like the forest and the savanna. There, certain kinds of biological diversity and life-forms thrive. In Ma's world, edges are where creativity flourishes—and the Bach Project seeks them out.

MA EQUATES THE BACH PROJECT with the classic children's tale about villagers who contribute cabbages, carrots, potatoes, and beef to a pot filled with boiling water—and a stone. "It's my version of Stone Soup," Ma told me. "I play the cello. This is the best of what I can bring to you. What would you like to put in the pot? How would you like to start a conversation? What are things you're thinking about? What are your needs—what is it that you're struggling with?"

Bach's *Suites for Unaccompanied Cello,* composed in the early 18th century, are the pinnacle of the instrument's repertoire. In 1890 a young Pablo Casals unearthed the suites in a musty shop near the harbor of Barcelona, Spain. Casals studied the suites for 12 years before playing one in public at the age of 25.

Ma learned the suites as a child in Paris (his violinist father taught him to memorize two bars at a time). He has recorded them three times, in his 20s, 40s, and early 60s. Each of his performances—whether a World War I commemoration at the Arc de Triomphe or a soulful rendering at his father's bedside—is unique to that moment. "He comes as close as any musician I've ever known to reinvigorate music, to breathe life into it," says pianist Richard Kogan, a friend of Ma's who played with him in a trio at Harvard.

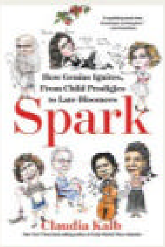
Bach and Casals have permeated Ma's being since childhood and continue to inform the man he strives to be. In the sixth suite, Ma notes, the composer wrote music for five strings rather than the cello's four, requiring wizardry on the part of the musician and participation from listeners, who must sustain notes in their ears even after the cellist plays them. For Ma, this dynamic works as a metaphor for how he lives his life: Reach for the unimaginable, and work together to make it happen. Casals, for his part, left Ma with a guiding principle that has lingered ever since the two met, when Ma was seven and Casals was in his 80s: Be a human being first, a musician second.

This generosity of spirit was clear to Denica Flesch, the founder of SukkhaCitta, a nonprofit that empowers textile artisans in Indonesia. During Ma's Day of Action in Jakarta, at the end of 2019, Flesch brought a group of women artisans from a rural village in East Java to meet the cellist.

He greeted them as he does everyone, as fellow human beings with vital wisdom to impart. "Tell me more," he likes to say. At first the artisans were too shy to look Ma in the eye. But as he sat and interacted with them, they grew to trust him and soon began singing songs from home as Ma accompanied them on cello. Later, after teaching Ma to create batik, the women told Flesch that they had never experienced such respect. "They really felt valued and seen," she says.

That 'Spark' of Genius

From National Geographic, *Spark* explores how and when inspiration strikes among high achievers such as Ma, Isaac Newton, Eleanor Roosevelt, and Maya Angelou. It's available wherever books are sold.



A key piece of SukkhaCitta's mission is environmental: to reduce toxic runoff from dyes that textile makers dump into local waters, including the heavily polluted Citarum River. Flesch has been working with the artisans to reclaim natural dyes for their designs—indigo leaves for blues, fruits for yellows, and mahogany and sappanwood for reds. But she is just one woman on a planet of billions. "We're such a small drop in the ocean," Flesch says.

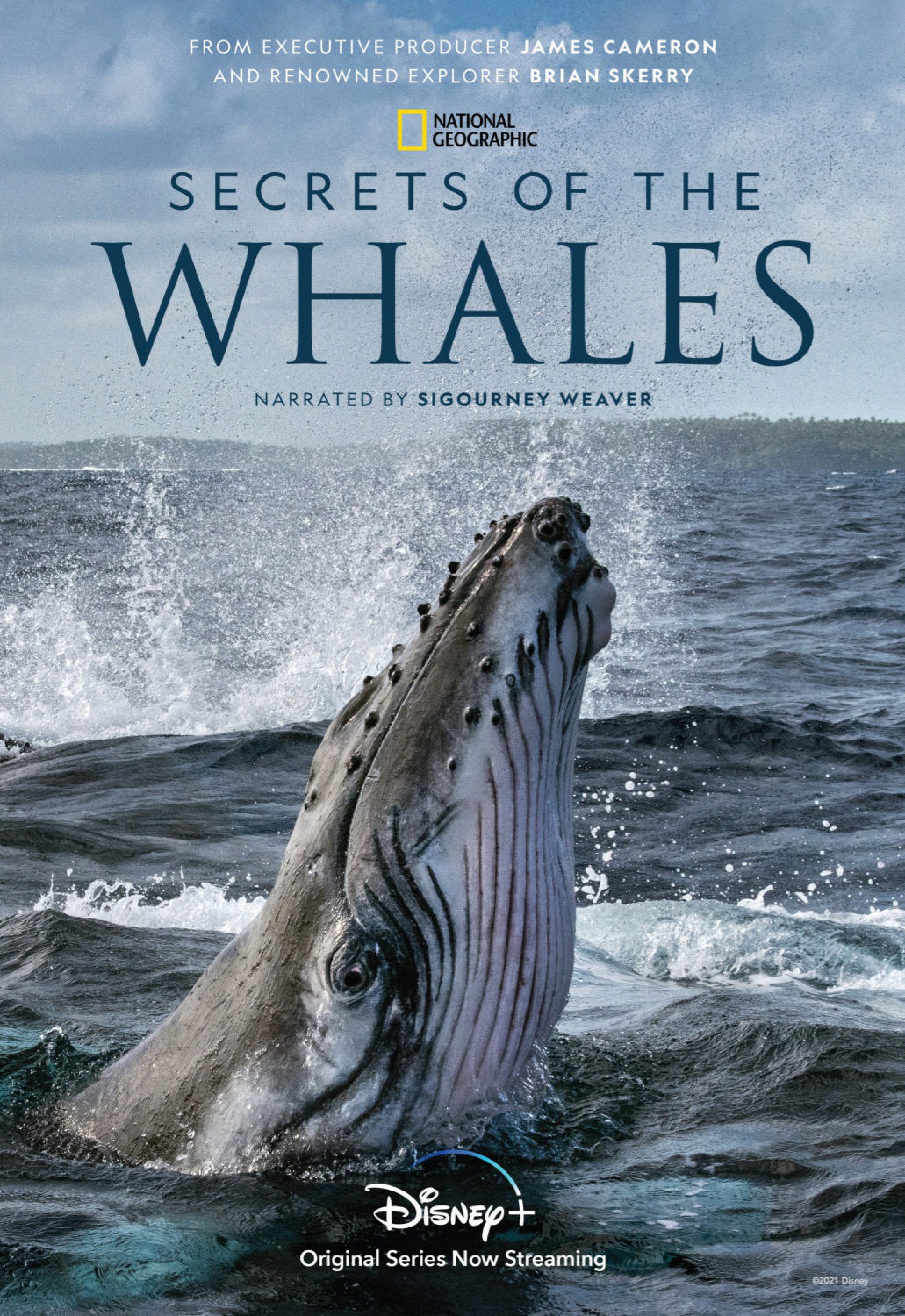
Ma's goal is to magnify her quest, to "take it to whatever next step is possible," he says. Last December he invited Flesch to do a takeover of his Instagram account. That allowed her to share SukkhaCitta's mission with his followers—more than 370,000, a number that dwarfs Flesch's typical outreach. Ma's support, she says, "makes everything we've been saying since the beginning more legitimate and relevant."

The Bach Project was intended to last two years, culminating in 2020. Then the pandemic hit. With careful quarantining procedures, Ma managed to perform in Taiwan in fall 2020. But plans for visits to Paris, Istanbul, Okinawa, and Tunis were put on hold or rescheduled. The cellist intends to resume his global journey as soon as it's safe to travel and gather; meanwhile, he's offered live and video performances online.

Last fall I asked Ma what kind of legacy he hopes to leave. "I'd like to live as lightly as possible," he said. Now a grandparent, he feels an obligation to be a good steward of the land and water we have inherited. It's our job, "from the littlest person to the oldest person everywhere, to say, We treasure this, this is our home, this is what gives us sustenance, this is what gives us meaning," he told me.

"In every possible thing that we do, let's fall in love with our planet."

Claudia Kalb reports on science, culture, and human behavior. She is the author of a series of cover stories on the origins of genius. Her latest book is *Spark: How Genius Ignites, From Child Prodigies to Late Bloomers.*



FROM EXECUTIVE PRODUCER **JAMES CAMERON**
AND RENOWNED EXPLORER **BRIAN SKERRY**

NATIONAL
GEOGRAPHIC

SECRETS OF THE WHALES

NARRATED BY **SIGOURNEY WEAVER**

Disney+

Original Series Now Streaming

©2021 Disney

In the past year, we've learned that the impossible is possible when it comes to the resiliency of the planet. We each have an important role in protecting the planet and can accomplish more together.

WHEN PEOPLE WHO LOVE THE EARTH COME TOGETHER,

ANYTHING IS POSSIBLE.

NATIONAL GEOGRAPHIC

PLANET POSSIBLE

START EXPLORING THE POSSIBILITIES AT

natgeo.com/planet

The Ocean Issue

IT'S FRAGILE, YET RESILIENT. EVERYWHERE, YET MOSTLY UNEXPLORED. THE OCEAN IS UNDER THREAT, BUT EACH OF US CAN HELP TURN THE TIDE.

40 **Secrets of the Whales**
Dialects, traditions vary within some whale species.

80 **Planet Ocean**
More than 70% of Earth is ocean. See how it's connected.

86 **Rescuing Reefs in Crisis**
Scientists assess human-caused harm to corals over time.

108 **28 Days Under the Sea**
Explorers devote weeks to the Mediterranean depths.

132 **The Searcher of the Deep**
He found the *Titanic,* but Robert Ballard is still on the hunt.

PHOTO: LAURENT BALLESTA

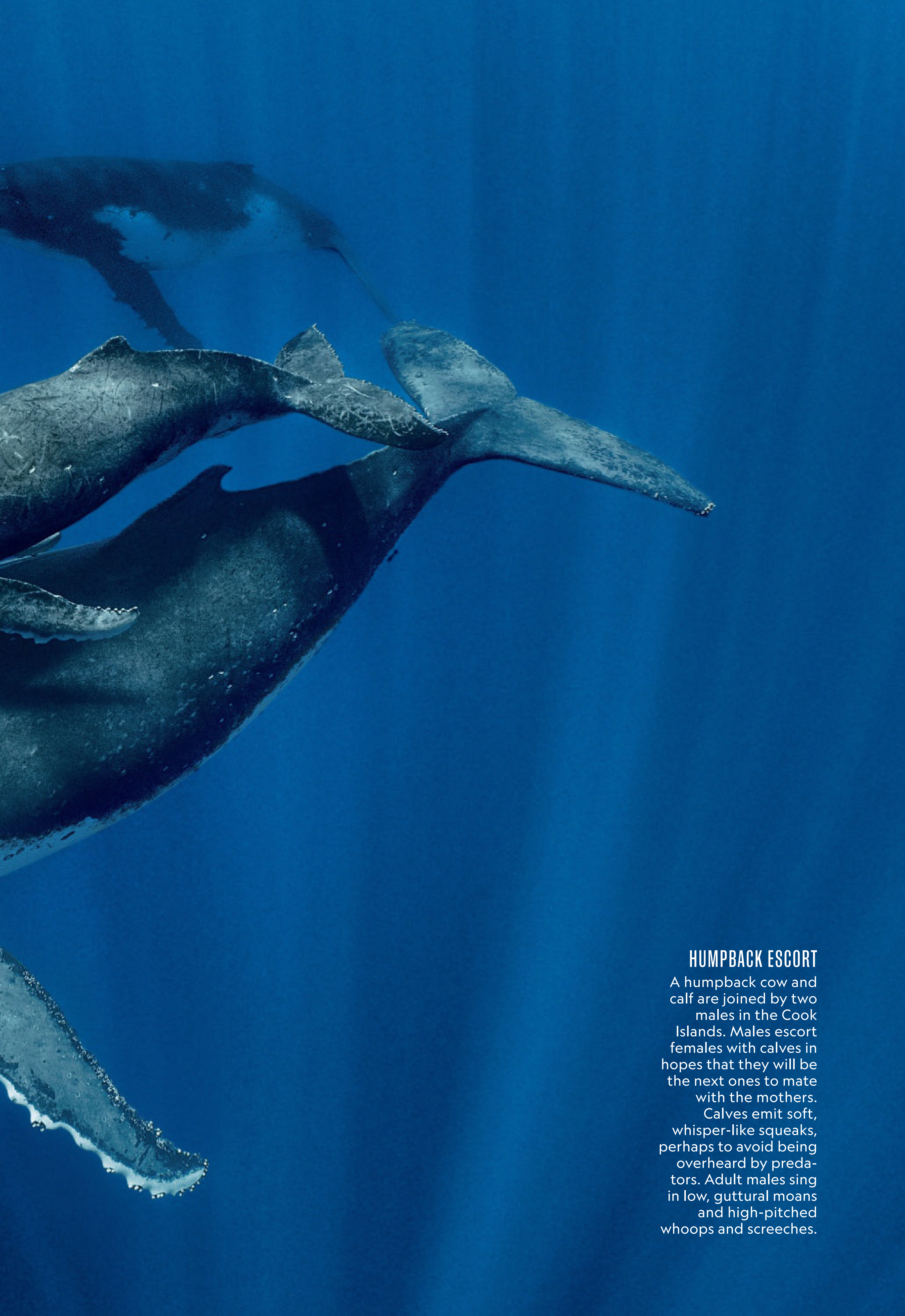
WHALE CULTURE
Nearly 2,000 belugas frolic each summer near Arctic Canada's Somerset Island, nursing their young, chattering in squeaks and whistles, and swimming about in shifting networks of companions and family. Scientists suspect many whale species share cultural traditions, much as humans do.

BY
CRAIG WELCH
PHOTOGRAPHS BY
BRIAN SKERRY

Secrets of the Whales

WE'RE LEARNING THAT SOME GROUPS OF WHALES AND DOLPHINS HAVE THEIR OWN DIALECTS, DIETS, AND ROUTINES—CULTURAL DIFFERENCES ONCE THOUGHT TO BE UNIQUE TO HUMANS.

KILLER FEAST
A killer whale, or orca, chases herring in a Norwegian fjord. Groups of killer whales (which are technically part of the dolphin family) have distinct eating habits. Some corral schooling fish. Others hunt sharks or seals, while some feast almost exclusively on salmon. These habits are partly cultural—learned behaviors passed down through generations.



HUMPBACK ESCORT

A humpback cow and calf are joined by two males in the Cook Islands. Males escort females with calves in hopes that they will be the next ones to mate with the mothers. Calves emit soft, whisper-like squeaks, perhaps to avoid being overheard by predators. Adult males sing in low, guttural moans and high-pitched whoops and screeches.

CLANSPEAK
Members of a sperm whale family near the Caribbean island of Dominica are part of a clan that's culturally distinct from others. Each clan communicates in its own dialect of click patterns, like Morse code.

JOHN FORD WANTED a whale's-eye view. One summer day in 1978 a pod of killer whales raced toward a pebbled beach on British Columbia's Vancouver Island. The young biologist was waiting in a wet suit and snorkel. The ghostly black-and-white procession steamed in like a team of U-boats, low and fast. Ford pressed on his face mask and slipped into the sea. In waters barely 10 feet deep, the creatures slowed and rolled to their sides. Bodies partially submerged, the fans at the end of their tails—their flukes—wagging, the whales began to twist and shimmy. One by one, each scuffed its side and belly on the stones, like grizzlies scratching against the pines.

Ford, age 66, has now studied killer whales, the largest dolphin and from the branch of the Cetacean order known as toothed whales, for more than 40 years. He's seen this phenomenon, called beach rubbing, countless times since that first underwater glimpse. He can't say for certain why the animals do it. He suspects it's a form of social bonding. A larger question, though, has gnawed at him for much of his career: How come these killer whales, or orcas, do it, but not their

The National Geographic Society, committed to illuminating and protecting the wonder of our world, has funded Explorer and Storytelling Fellow Brian Skerry's work to increase awareness about the sea since 2014.

ILLUSTRATION BY JOE McKENDRY

nearly identical neighbors just to the south?

Beach rubbing is routine among this population, called northern residents because they ply inland seas during summer and fall between the Canadian mainland and Vancouver Island. Not so their neighbors to the south. The orcas around the border with Washington State, where I live, have never been documented performing this ritual.

Washington's killer whales, called the southern residents, instead have their own conventions. They hold "greeting ceremonies," facing off in tight lines before exploding in underwater parties of rubs and calls. That's exceedingly rare up north. Southern residents are aerialists, performing twisting leaps and belly flops. Northern residents breach far less. Some years the southern residents push dead salmon around with their heads. Not the northerners: They occasionally headbutt one another, bumping noggins like bighorn sheep. "They just swim at each other and sort of collide," Ford says.

The two populations don't even converse with the same vocabulary. Northern residents emit elongated, shrill, metallic squeals that sound like air escaping balloons. Southern residents add monkey hoots and goose honks. To Ford's practiced ear, the pitches and intonations sound as different as Mandarin and Swahili.

Yet in every other meaningful way, the northern

SECRETS OF THE WHALES

Follow Brian Skerry on his travels to document whale culture. Watch all four episodes on Disney+, starting Earth Day, April 22.

Disney+

and southern residents are indistinguishable. For months at a time, they occupy adjacent seas. Their ranges overlap. Although many varieties of killer whales exist around the world, the northern and southern whales share almost identical genetics. From the northern Pacific to the seas around Antarctica, killer whales also have varying diets. Some eat sharks, porpoises, penguins, or manta rays. In Patagonia, they launch onto rocky shores and pluck seal pups off the beach. In Antarctica, killer whales flush Weddell seals off floating ice, teaming up to swamp floes and wash dinner into the drink. But the northern and southern residents are both pescatarians, and eat mostly just one species: Chinook salmon.

How could two groups from essentially the same place be genetically similar and yet speak and act so differently? For years, Ford and a few colleagues would only whisper what this paradox implied. Is it possible that these complex social beings weren't driven solely by the inherited twitch of genetic instinct? Were killer whales passing on unique traits influenced by more than their environment or DNA? Could whales have their own cultures?

The very notion seemed blasphemous. Anthropologists long had considered culture—the ability to socially accumulate and transfer knowledge—strictly a human affair. But researchers had described how songbirds learn dialects and transmit them across generations, and Ford proposed that killer whale groups might do the same. Then he started hearing about the findings of biologists studying a creature a world away: the sperm whale. Those scientists had been building a case that some whale species act and communicate differently based on how they're raised. It appeared these cetaceans might carry on diverse traditions, just as some humans eat with chopsticks while others use forks.

Today many scientists believe some whales and dolphins, like humans, have distinct cultures. Researchers see signs in sperm whales in the Galápagos and the Caribbean, in humpbacks across the South Pacific, in Arctic belugas, and in the Pacific Northwest's killer whales. The possibility is prompting new thinking about how some marine species evolve. Cultural traditions may help drive genetic shifts, altering what it means to be a whale. But this idea is also reshaping our view of what separates us from these aquatic beasts. Whale culture, it seems, is rattling timeworn conceptions of ourselves.

H

HUMANS ARE A NARCISSISTIC BREED. Throughout history we've vacillated between seeing animals through the lens of our own behavior and refusing to accept that we're anything alike. This is particularly true of whales. They're often viewed as almost human or not like us at all. We anthropomorphize or insist on our own uniqueness. Neither, of course, is entirely correct.

Whales reside in a foreign place we're just coming to understand. It's hard to imagine a home less like ours. The deep ocean is a universe we've seen less of than the surface of the moon. There are mountains and rivers but few borders. Life traverses a vertical plane. It's so dark that sight is of limited value. Entire relationships are forged through sound.

And yet, as we spend billions scanning the heavens for alien life, the mysteries we're unraveling beneath the waves reveal foreigners here at home that are more like us than we knew. Whales' alliances, the intricacies of their

Whales' alliances, their intricate conversations, and how they attract mates or care for their young seem eerily familiar. The mysteries we're unraveling beneath the waves reveal creatures a lot like us.

conversations, and the ways they care for their young seem eerily familiar.

Some may even openly mourn. In 2018 a southern-resident killer whale known as Tahlequah pushed the carcass of her newborn, which had died shortly after its birth, around with her snout for 17 days. "For years scientists vigorously avoided using emotional terms like happy, sad, playful or angry when describing animal behavior," writes Joe Gaydos, who oversees a university program in Washington State to protect marine life through science and education. But Gaydos and many whale biologists believe Tahlequah's behavior was a show of grief.

When photographer Brian Skerry first mentioned his interest in exploring the culture of these remarkable animals, one group leaped to mind. I live four miles from Puget Sound, where three pods of southern-resident killer whales spend a portion of their year zipping about in tight formations like squadrons of Air Force Thunderbirds. When their dorsal fins break the surface near shore, crowds gather with cameras, hoping to catch a memorable hop or acrobatic lunge. What secrets might these whales carry? Could knowing them help us live better together?

Scientists have long understood that many whale actions must be picked up from peers or elders. It's learned behavior and hardly shocking. Even Aristotle knew animals learned from one another. Songbirds raised away from their own families "utter a different voice from their parents," he wrote. Charles Darwin noted that animal traps eventually must be moved because wild creatures "imitate each other's caution."

While genes determine the shape and function of a creature's body, encoding instructions for essential traits and behaviors, social learning is received wisdom, the development of neural connections that let animals learn from the knowledge of those around them. Scientists generally agree that culture requires that behaviors be socially learned and shared widely, and that they persist. As groups of animals transmit multiple learned behaviors, they can develop sets of habits wholly distinct from others of their species. For example, the ability to throw is genetic. But throwing a curveball requires social learning, and playing baseball instead of cricket is culture.

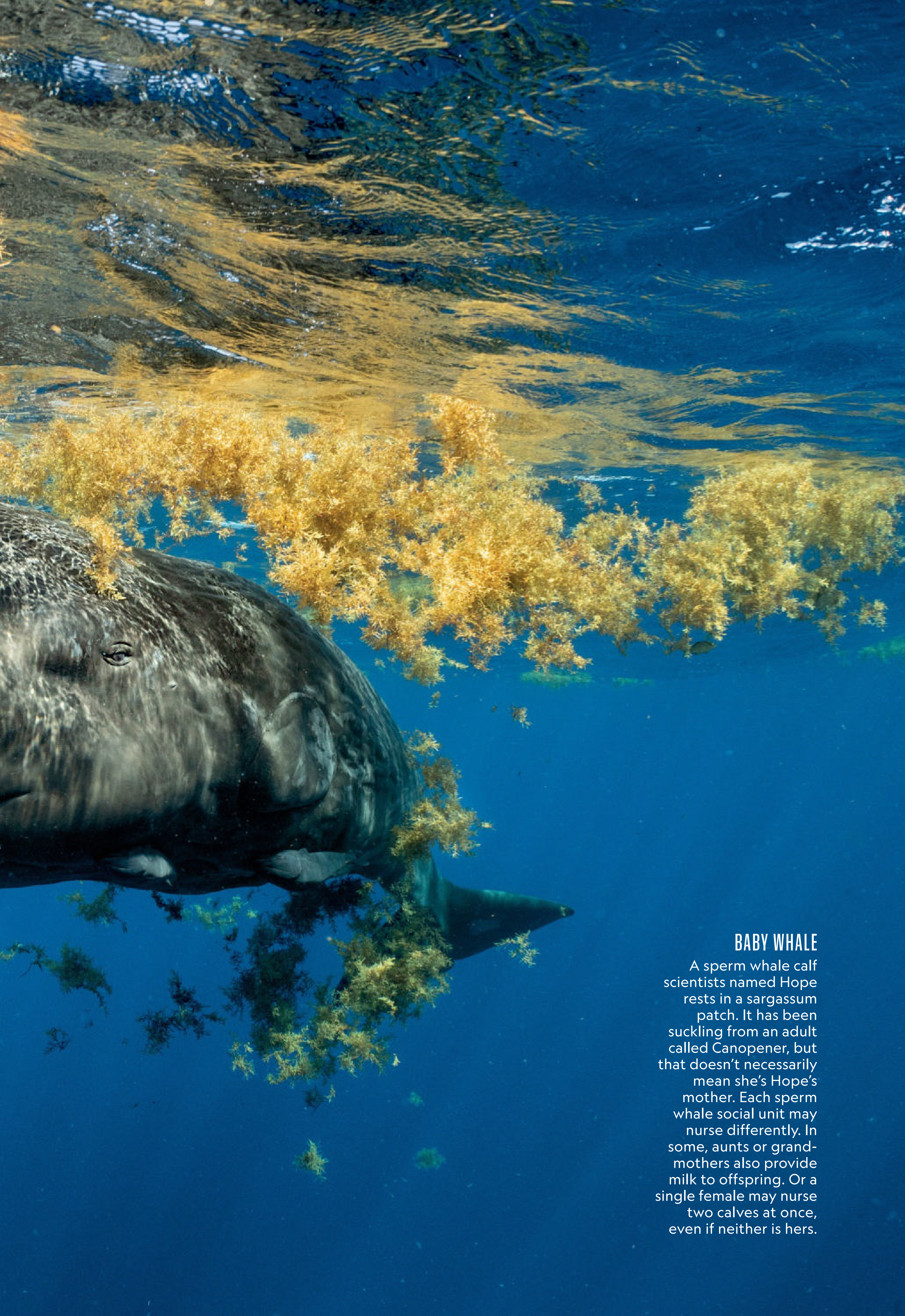
The danger, though, is to confuse culture with intelligence. Scientists don't all agree on whether intelligence is an essential ingredient for culture. Social learning cuts widely across the animal kingdom, and not just among beings we consider "smart"—whales, primates, crows, elephants. Bumblebees may choose flowers based on the behavior of experienced bees. Mongooses learn from siblings and cousins to break open eggs or smash beetles.

But being smart clearly helps. And cetaceans' capacity for learning captured our imaginations early. For decades we've packed marine theme parks, applauding killer whales, belugas, or bottlenose dolphins that sing or vault through hoops in giant pools. These feeble attempts to corral their skills barely scratch the surface of their talents. In 1972 a scientist studying a bottlenose dolphin calf named Dolly exhaled cigarette smoke onto the window of her enclosure during a break. "The observer was astonished when the animal immediately swam off to its mother, returned and released a mouthful of milk which engulfed her head, giving much the same effect as had the cigarette smoke," researchers wrote at the time.

Among some whales, intelligence may even be an evolutionary response to culture, as social animals spread learned wisdom far and wide. For culture to exist, individuals must come up with new ways of doing things that get shared among peers. And whales can be shrewd innovators. A few hungry sperm whales off Alaska in the late 1990s found new ways to snack: They stripped black cod off commercial fishing boat longlines. Using underwater cameras, scientists recorded a whale delicately grabbing a line with its massive jaw, creating tension, and then sliding its mouth up the strand until the vibrations popped off a fish. The practice, previously rare, quickly spread. In the Gulf of Maine, in 1980, one humpback was seen hunting in a new way. Before blowing bubbles around schools of sand lances to disorient them, the whale smacked the surface with its fluke. Humpbacks regularly use the bubble technique, but the fluke slap was new. It's not clear how it helps, but by 2013, scientists counted at least 278 whales that hunted this way.

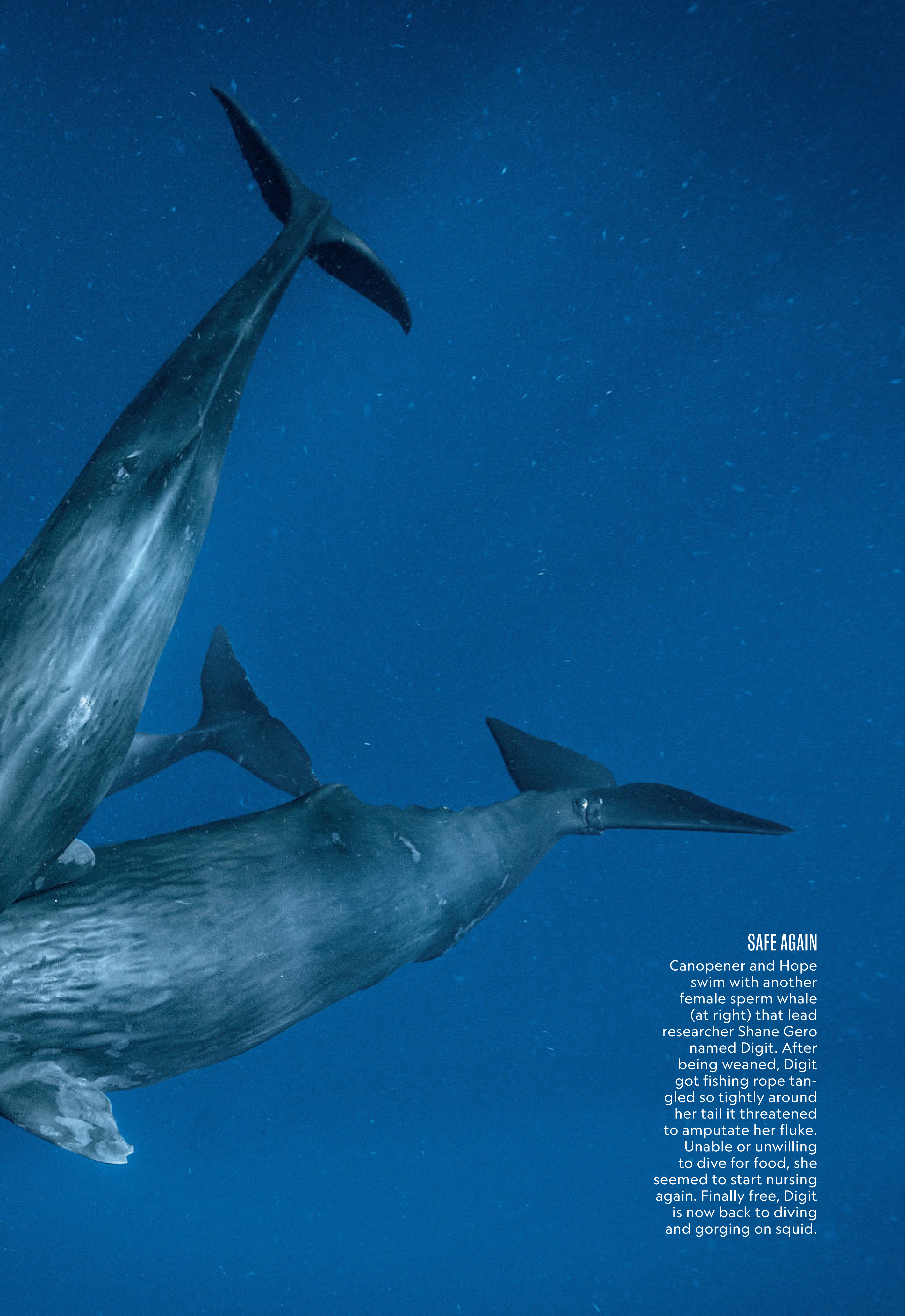
For years scientists thought animals were incapable of broad, sustained, intergenerational sharing. That notion began changing in 1953. That year, a young macaque, Imo, was spotted on Koshima island, Japan, washing a sweet potato in a stream. Before then, the island's macaques simply wiped dirt off their food. Soon, scientists documented macaques by the dozens washing them instead. Long after Imo died, macaques still carted potatoes to shore to dunk them in the sea.

ADDITIONAL FUNDING FOR THE PHOTOGRAPHY IN THIS ARTICLE WAS PROVIDED BY THE PHILIP STEPHENSON FOUNDATION AND BY FOCUSED ON NATURE.



BABY WHALE

A sperm whale calf scientists named Hope rests in a sargassum patch. It has been suckling from an adult called Canopener, but that doesn't necessarily mean she's Hope's mother. Each sperm whale social unit may nurse differently. In some, aunts or grandmothers also provide milk to offspring. Or a single female may nurse two calves at once, even if neither is hers.



SAFE AGAIN

Canopener and Hope swim with another female sperm whale (at right) that lead researcher Shane Gero named Digit. After being weaned, Digit got fishing rope tangled so tightly around her tail it threatened to amputate her fluke. Unable or unwilling to dive for food, she seemed to start nursing again. Finally free, Digit is now back to diving and gorging on squid.

Then, in 1999, Andrew Whiten, a cognitive scientist with Scotland's University of St. Andrews, published a landmark paper with primate experts, including Jane Goodall. They noted that dozens of chimpanzee traditions—grooming, rain dancing (strutting about at the first signs of precipitation), cracking nuts with hammers, poking termite mounds with sticks—appeared across some chimp communities but not others. "If you watch a chimpanzee long enough and check out these behaviors, you can pretty much tell where that chimp came from," Whiten tells me. And watching people behave is often how we identify human culture.

Not everyone is convinced. Some researchers argue that genetic or environmental variables could've prompted some of these behaviors. The chimpanzees weren't all the same subspecies. They ranged from coastal Guinea to Uganda, 2,700 miles apart—far enough, some suggest, that ecological differences could have influenced the primates' activities.

But a new way of thinking about wildlife behavior and group culture, less centered on humans, was taking root. And as Whiten and others built on their initial work, skeptics found claims harder to dismiss—especially when it came to creatures longer than city buses that use sound to find their prey a mile below the sea's surface.

MOTHER'S MILK
This is one of the first images of a sperm whale nursing. Scientists had wondered how these mothers gave milk to their long-jawed young. Females have slits that contain hidden nipples. When a calf is hungry, it pushes its jaw into the slit and milk is released, allowing it to feed.

W

"WHOA, WHOA! RIGHT HERE!" Shane Gero shouts, and begins counting. Eight sperm whales bob off our port side, half-submerged in the cobalt Caribbean. They're gunmetal gray and as smooth and cylindrical as airplane fuselages. The whales are taking a breather—literally. They've just surfaced to draw oxygen deep into their enormous, squared-off heads. Soon they'll dive and use some of that air to converse.

We're aboard *Balaena*, a 40-foot sailboat, swaying offshore of the West Indies island nation of Dominica. The tiny country's rain-soaked peaks, now shrouded in mist, are partly why we're here. Those small green mountains block gales and keep deep leeward waters calm—ideal conditions for studying sperm whales. And Gero, crisscrossing the deck barefoot in board shorts, has studied more sperm whale families up close than perhaps any human in history.

Since 2005, the adjunct professor at Denmark's Aarhus University and Canada's Carleton and Dalhousie Universities has come to this glittering swirl of sargassum and spray to study these leviathans. Rather than finding a "monomaniac incarnation" of "malicious agencies" as Herman Melville described the sperm whale in *Moby-Dick*, Gero sees peaceful, playful animals. He can identify dozens on sight. There's Canopener, who toys with researchers, pulling close to their vessel before rolling sideways to eyeball

Gero's crew. There's Digit, who almost perished after swimming through fishing gear that lassoed her tail, nearly amputating it while preventing her from diving to eat. (She's since healed.) The one with the serrated fluke is called Knife; the one with the weird scoop in his was Spoon.

The whales he knows are local "island specialists," Gero tells me. He follows them as they move through underwater canyons off Dominica, between the islands of Guadeloupe and Martinique. He has tracked them sleeping, giving birth, nursing, making their first dives, playing with cousins, dying. He's recorded them swimming deeper than most submarines travel. He knows their lives so intimately his kids at home can recite their names.

But today, after more than a week at sea, we woke to find the locals gone, replaced by the eight outsiders riding swells around us. Gero is gregarious by nature, yet this is the most excited I've seen him. He's shouting for students to drop underwater recorders called hydrophones. He warns them to get their cameras ready to photograph flukes, which, like fingerprints, help identify individual whales as they dive.

These new whales are animals he barely knows, itinerant vagabonds from a second whale community. They occasionally share space with the regulars, but never interact with them. To me, they're sleek and glorious but not so different from the local whales we spotted yesterday. To Gero, they are unmistakable evidence that Dominica is home to parallel whale traditions—two cultures as divergent

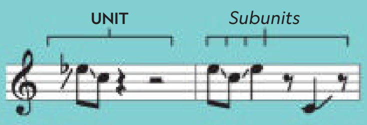
Whale Songs Decoded

Yaps and fin slaps, growls and groans—whales use a wide range of sounds to communicate. But only five whale species are known to sing, with humpbacks the unrivaled musical masters of the sea. As juveniles, male humpbacks start picking up songs in bits and segments, listening to their peers in a form of social learning (females vocalize but don't sing). Once they master a song, it changes slightly, eventually completely, as the population rearranges the tunes over days, weeks, and years. Songs have a complex structure similar to the repetition and rhymes of poetry, and all the males from the same ocean basin sing the same tune until it is modified yet again. This song, recorded and translated into human music by composer David Rothenberg, is from one humpback repeatedly singing one song off the coast of Maui, Hawaii.

Listen to David Rothenberg's rendition of the whale song. Use your phone's camera to scan the QR code.

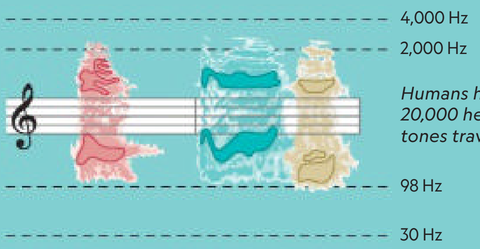
THE SHAPE OF SOUND

Humpback songs can be heard by the human ear, but their pace is slower than ours, making it hard to recognize melody. Researchers first identified their "songs" by printing out recorded spectrograms, which show pitch and timing. Visualized as shapes, song patterns emerged. Here we've translated a whale song into both shapes and human musical score.



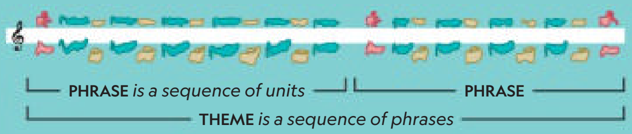
Vertical position denotes pitch; lower notes have lower tones.

The notes above are the first segment of the whale's song. Below we see the same segment, represented as a spectrogram translated into a visual shape of sound, to capture pitch and timing. Color distinguishes shapes and makes patterns easier to recognize: same color, same sound.



Humans hear best at 20 to 20,000 hertz (Hz). Lower tones travel farther in water.

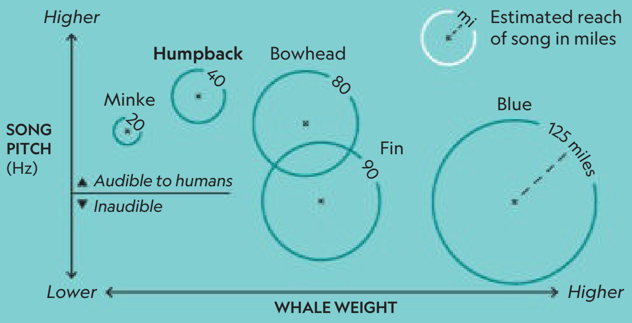
These simplified, colored musical units are joined into longer patterns to form phrases, which are then connected to construct themes. The themes are similar to individual lines of poetry or words in a song.


PHRASE *is a sequence of units*
PHRASE
THEME *is a sequence of phrases*

A **SONG** is a sequence of themes (labeled in our score as **A** through **F**). Humpback whale songs typically span five to 30 minutes. A whale may repeat a song many times during marathon stretches that can last up to 22 hours. Experts call these marathons **SONG SESSIONS.**

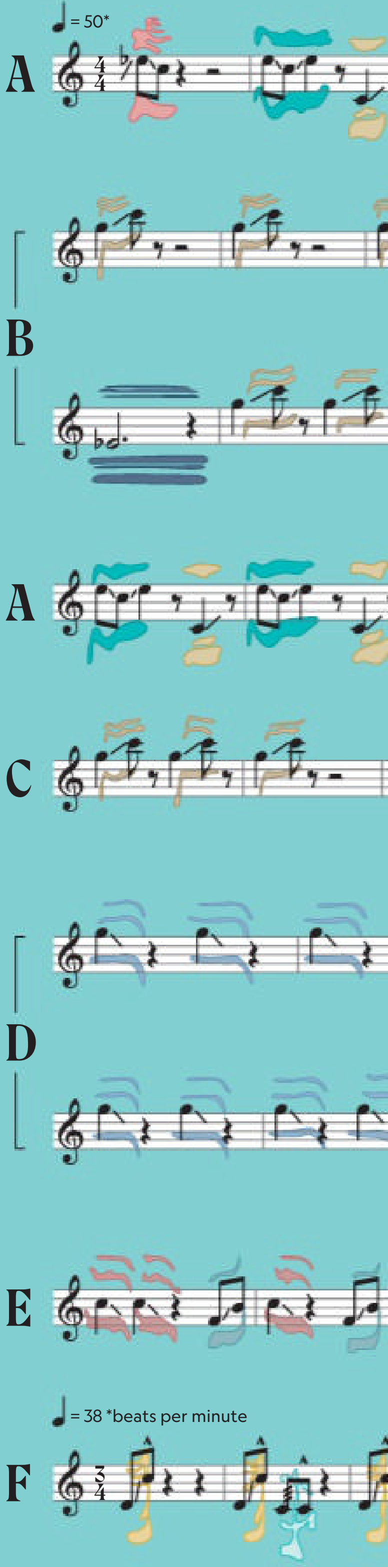
HOW FAR SONGS CAN TRAVEL

Five whales—blue, bowhead, fin, humpback, and minke—are thought to sing. Smaller whales typically produce higher frequency signals, while massive blue and fin whales can sing at pitches too low for humans to hear. Low tones can travel farthest, but reach is affected by natural ocean sounds, such as waves, and human-caused noise pollution, such as shipping. Sound travels roughly four times as fast in water as in air.



HOW TO PLAY A HUMPBACK MELODY

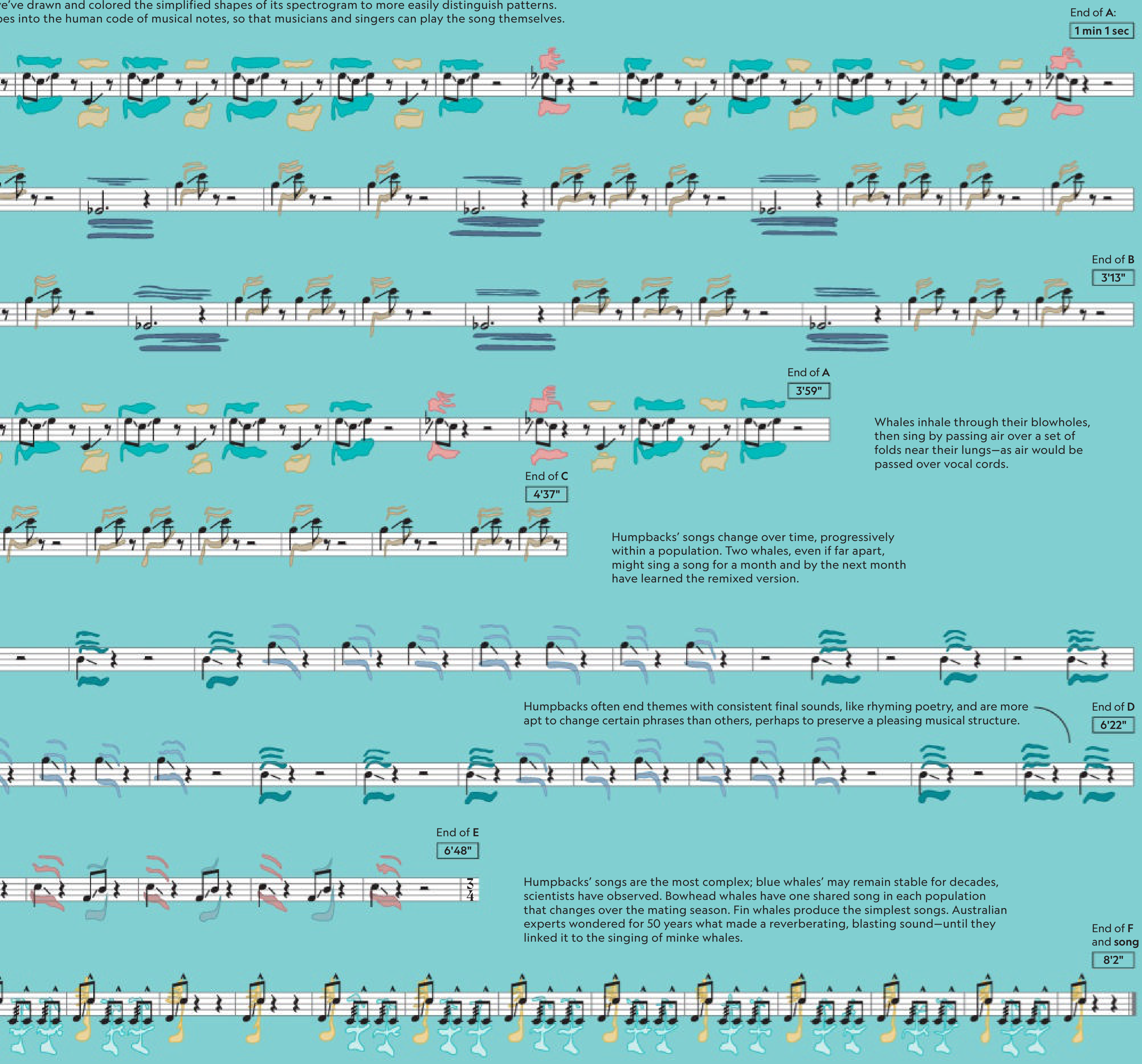
This humpback whale song recorded in Hawa
understand the complexity of its structure, w
Similarly, we've translated the simplified shap



ALBERTO LUCAS LÓPEZ, NGM STAFF. MESA SCHUMACHER. SONG RECORDED AND TRANSCRIBED BY DAVID ROTHENBERG.

SOURCES: OLIVIER ADAM, SORBONNE UNIVERSITY, PARIS, FRANCE; MICHAEL NOAD, UNIVERSITY OF QUEENSLAND, AUSTRALIA; JOHN RYAN, MONTEREY BAY AQUARIUM RESEARCH INSTITUTE; OUTI M. TERVO AND OTHERS, *PLOS ONE*, DECEMBER 2012

ii lasts eight minutes and two seconds. It's made up of a series of themes (**A**+**B**+**A**+**C**+**D**+**E**+**F**). To better
e've drawn and colored the simplified shapes of its spectrogram to more easily distinguish patterns.
es into the human code of musical notes, so that musicians and singers can play the song themselves.

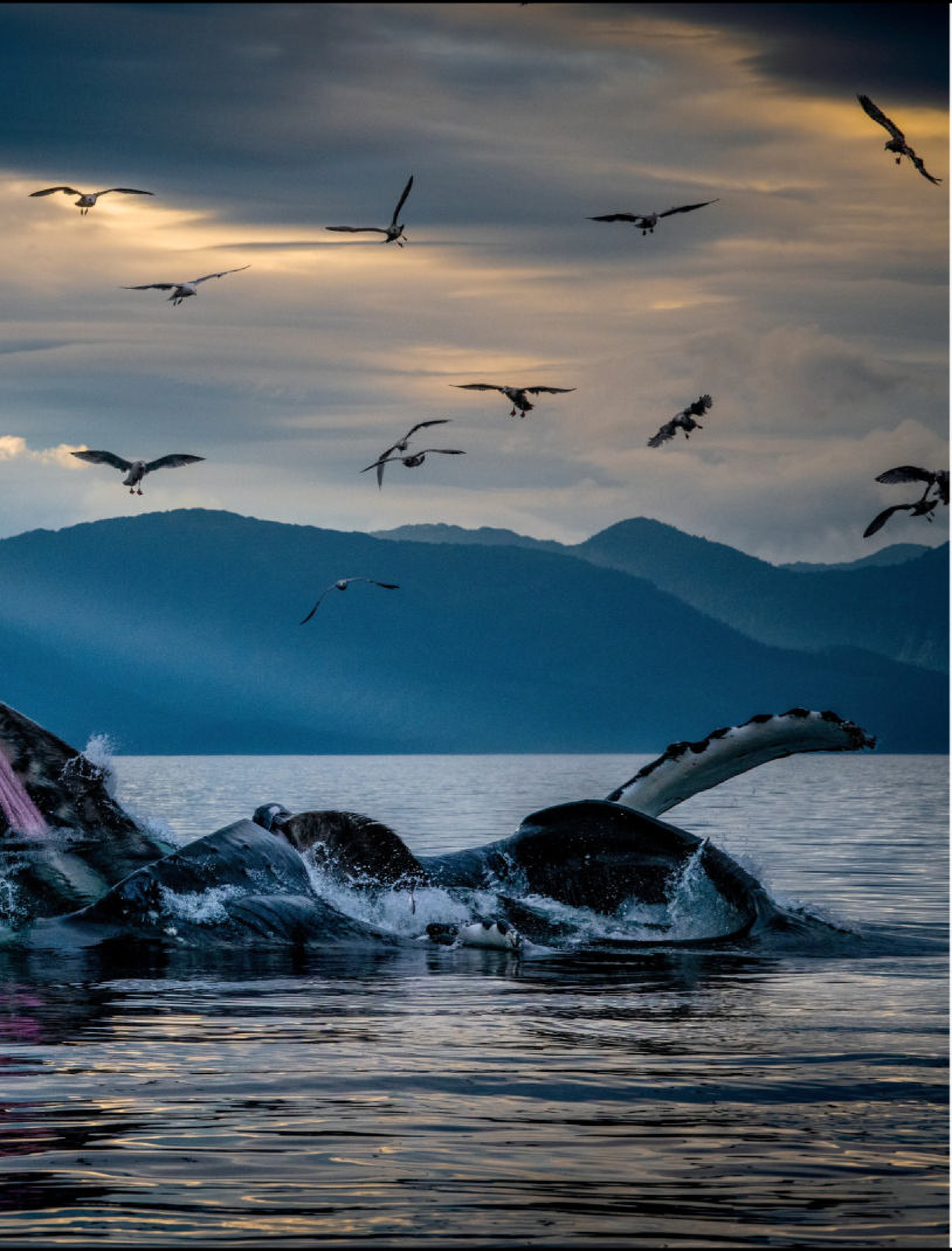


Whales inhale through their blowholes, then sing by passing air over a set of folds near their lungs—as air would be passed over vocal cords.

Humpbacks' songs change over time, progressively within a population. Two whales, even if far apart, might sing a song for a month and by the next month have learned the remixed version.

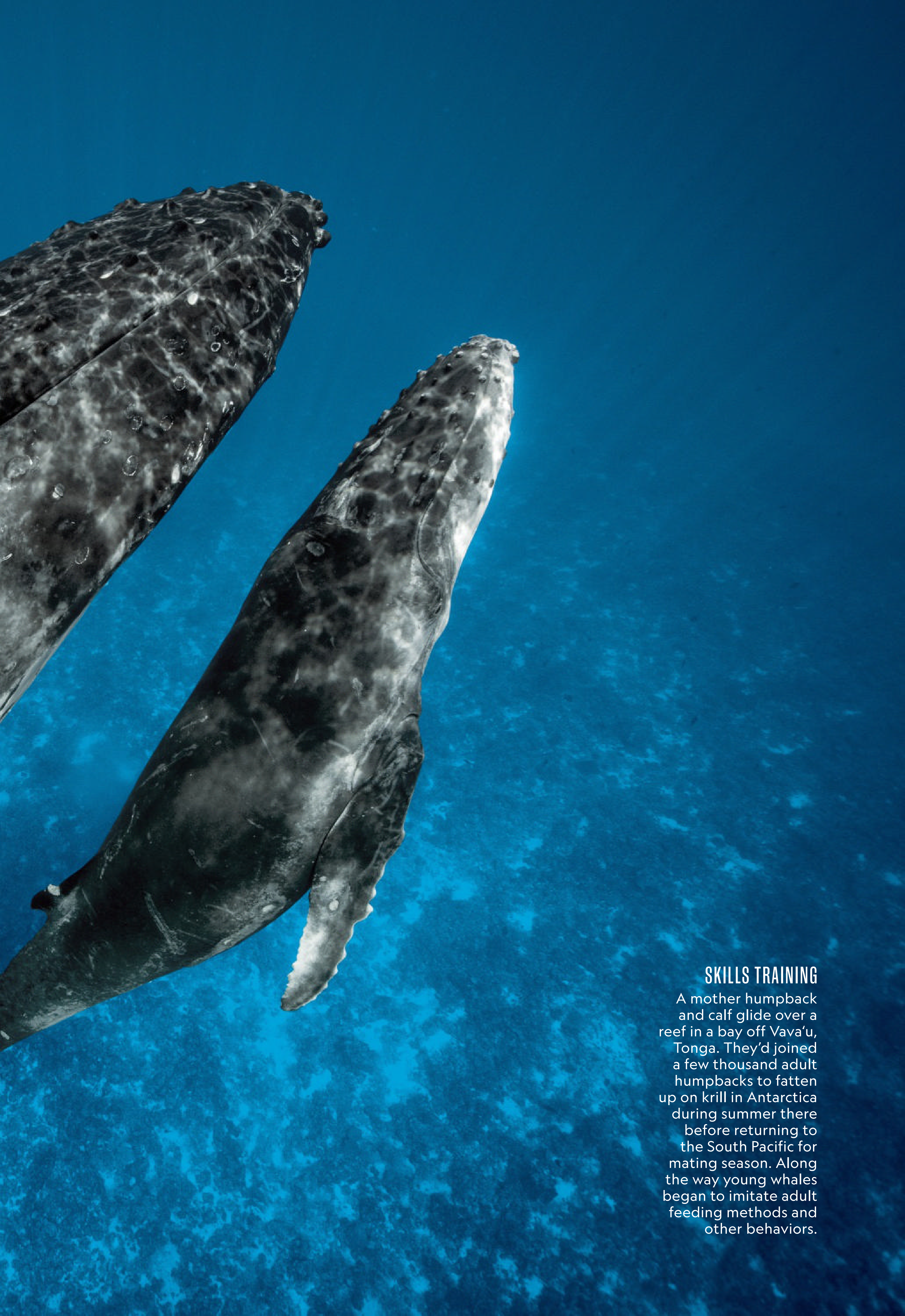
Humpbacks often end themes with consistent final sounds, like rhyming poetry, and are more apt to change certain phrases than others, perhaps to preserve a pleasing musical structure.

Humpbacks' songs are the most complex; blue whales' may remain stable for decades, scientists have observed. Bowhead whales have one shared song in each population that changes over the mating season. Fin whales produce the simplest songs. Australian experts wondered for 50 years what made a reverberating, blasting sound—until they linked it to the singing of minke whales.



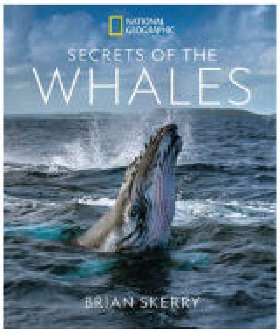
A FEEDING STRATEGY

Humpback whales, working in teams, circle herring with disorienting curtains of bubbles off Alaska's coast, then shoot up from below with their mouths open. This innovation developed among unrelated groups of humpbacks but is now a widely adopted practice.



SKILLS TRAINING

A mother humpback and calf glide over a reef in a bay off Vava'u, Tonga. They'd joined a few thousand adult humpbacks to fatten up on krill in Antarctica during summer there before returning to the South Pacific for mating season. Along the way young whales began to imitate adult feeding methods and other behaviors.



SECRETS OF THE WHALES (THE BOOK)

Photographer Brian Skerry traveled from the Arctic to the South Pacific to capture spectacular and intimate images of several whale species, unveiling their complex lives and societies. Available online and in bookstores on April 6.

as farmers and nomadic hunter-gatherers.

The roots of this knowledge come from the man helming our sailboat, Gero's mentor, Hal Whitehead. Curly mopped, hat brim blown skyward by wind, the professor at Dalhousie University steadies our craft with one eye on our visitors. Sperm whales travel in lifelong, female-led social units (males are squeezed out in their early teens) of about a dozen. In the 1980s and 1990s, Whitehead tracked some of these social units across the Galápagos, partly as an excuse to live at sea. Then "I just became really interested in them," he says. He and Luke Rendell, a researcher at the University of St. Andrews, started unspooling their cultural mysteries by documenting patterns of sperm whale chatter.

Sperm whales use the world's largest brains to operate nature's largest sonar system. They send pressurized air through their snout, creating clicking sounds. They string these clicks together in rhythmic codas, rather like Morse code. Each coda lasts seconds or less. Some are three clicks; some may be a dozen or more. Over decades Whitehead recorded clicks by the thousands.

He had no clue what the whales were saying, but one day in his lab in Nova Scotia, Whitehead created a chart summarizing recording data from all these whale groups. He spotted a trend: Roughly half made a common repertoire of calls. Their codas had similar patterns. Other units used different arrangements. "I was blown away," Whitehead recalls. He bounded up concrete steps to Rendell's office. Rendell got it too. These small whale units were part of something bigger—whale clans of hundreds or thousands. And each clan was speaking its own dialect.

Why would these animals, many of which had never met, have shared common calls? It's a group moniker, the men theorized, a way to say, "I'm one of you." They knew small groups spent time with others in their clan, but never with outsiders. And in the inky black of the sea, sound is how they'd see who was around.

Whitehead suspected click-codas were similar to human markers of cultural identity. Think, he says, of the gear worn by English Premier League soccer fans. "The Manchester United supporters parade around with a red scarf, the Manchester City with a blue scarf," Whitehead tells me as dusk settles over the Caribbean. They don't all know each other, and don't mingle. Yet fans find their way to pubs to watch matches together. "It suggests this higher-level thing that's really important to the whales," Whitehead says.

Over time he, Rendell, and others also documented that whales in two distinct clans in the Galápagos had startlingly different habits. In one, whales cruised the sea in meandering formations, while in the other they swam in straighter lines. One clan stayed close to land, the other moved farther offshore. During El Niño periods, when waters warmed, whales in both clans struggled to get enough food, but one clan had a harder time than the other.

For whales, it appears "there is this boundary between us who learn from each other and do

PICKY EATERS

A killer whale off New Zealand hunts rays. Orcas can become so culturally attached to their food that they won't switch prey. In 1970 a few mammal-eating killer whales were captured for the marine park trade off the coast of British Columbia and refused to eat for more than 70 days rather than consume salmon, the prey of neighboring killer whales.

LEARNING TO HUNT

Near Sea Lion Island in the Falklands, female killer whales in a couple of families have learned to nab an elephant seal pup from a nursery and use it to practice hunting with their off-spring before eating it.

SHARING THE BOUNTY

Killer whales, like fishing boats, follow schools of herring in the Norwegian Arctic. The orcas herd the fish into balls by flashing their underbellies, blowing bubbles, and slapping their tails to stun the fish. Researchers discovered this behavior happens less often when fishing boats are active nearby.

FISH THIEVES

Some whales see fishing boats as opportunities. In Norwegian waters, killer whales like this one may wait for herring to slip from the haul or may pluck fish directly from a net. In Alaska, sperm whales have learned to strip black cod one by one from fishing boat longlines.

things one way," Gero explains, "and they who don't learn from us and do things differently."

The idea that whales have cultures at all, let alone that they segregate themselves into cultural groups as humans do, was controversial when Whitehead and Rendell presented it in 2001. "It is sad to see such rich empirical material, about such wonderful creatures, harnessed to such an impoverished theoretical agenda," one British anthropologist sneered.

Twenty years later, some skepticism remains. "I would never say that sperm or killer whales do not have culture, but I would say that the evidence for culture is stronger in many other animal species," such as humpbacks and songbirds, says Peter Tyack, a scientist with Woods Hole Oceanographic Institution who studies cetacean communication. Genetics, animal development, and the environment can work in complex ways that make it hard to definitively link behavior to culture. "It is essential for scientists to be honest and humble about how little we know about the cultures of any animal species."

And yet whale scientists increasingly embrace Whitehead's view, says Sarah Mesnick, with the National Oceanic and Atmospheric Administration. "It's gaining acceptance because more and more people are observing it," she says.

Gero, for example, found similar divisions among sperm whale clans in an entirely different sea than his mentor: the Caribbean. And Gero's ability to drill down into life with individual whales has strengthened Whitehead's case.

One afternoon we spot a female sperm whale named Rounder. She's floating at the surface with two calves, only one of which is hers. Baby whales don't dive deep for squid, Gero explains, so an adult protector stays topside as the unit hunts. We're watching Rounder babysit.

Every unit does this differently. Some let the young slip beneath their bellies to suckle. In some units, calves get watched by nonrelatives, but get milk only from mom. In Rounder's group, moms and grandmothers share babysitting and nursing duties, but only for calves in their bloodline. In another, one female plays wet nurse to two calves at once—even though neither is hers.

Gero also discovered that small units within clans appear to emit family-specific codas, almost like surnames, while individuals communicate in click patterns with subtle, signature variations, like first names. Using nothing but clicks, Gero can tell which whale in a unit is speaking about 80 percent of the time—"way better than random chance," he says.

Gero even recorded baby sperm whales making random clicks before winnowing their repertoire. They were zeroing in on their clan's dialect, like infants babbling before saying "mama." They were acquiring cultural norms before him in real time.

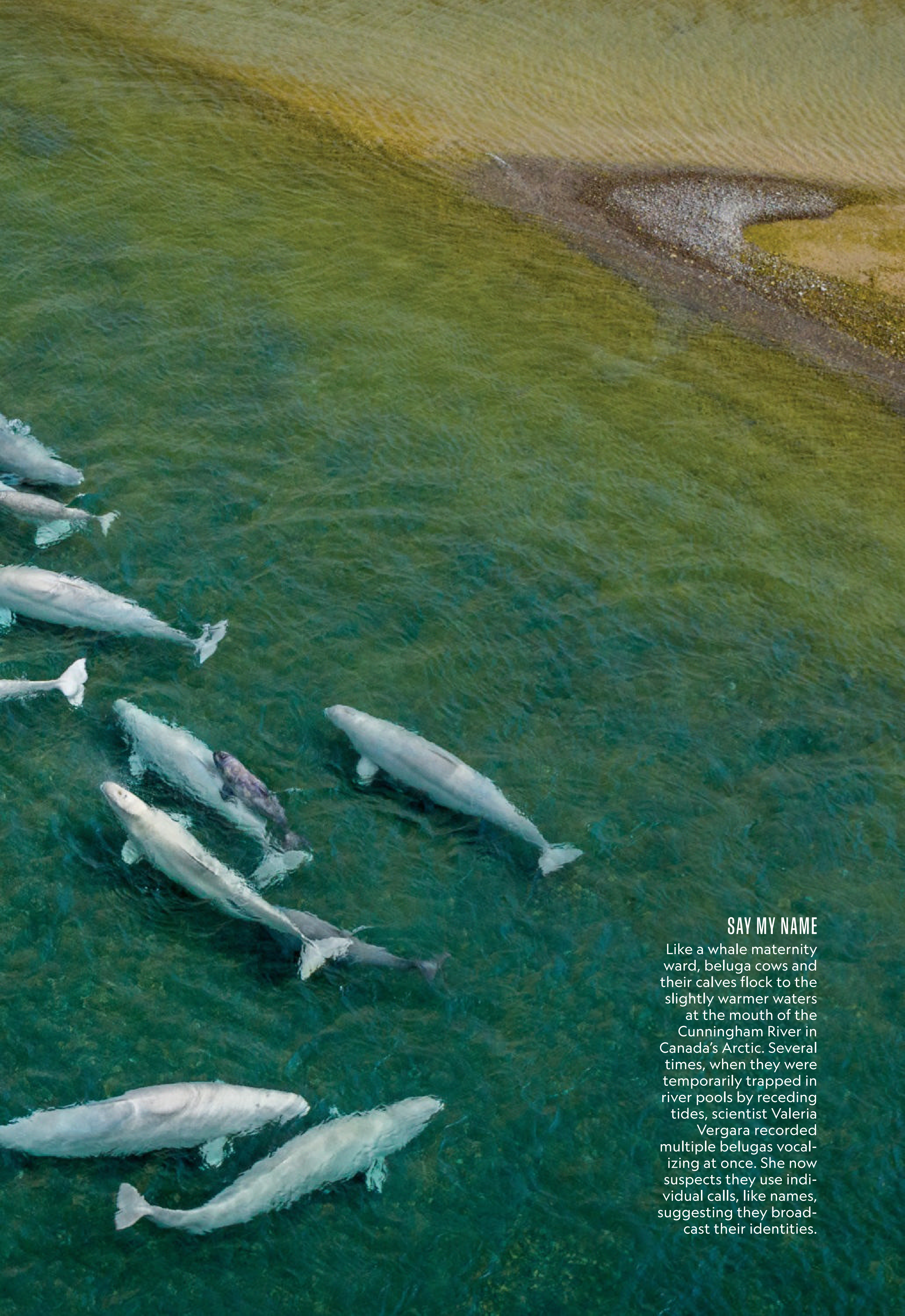
BACK HOME ONE AFTERNOON, I sit down to sample some whale culture for myself. Slapping on headphones, I click a computer file. What I hear next is deep and guttural, like the low rumble of a bass saxophone dipped in water.

CULTURAL MIGRATION

Belugas appear gray as calves and turn white as they age. Unlike salmon, which are born with the instinct to follow specific migration routes, young belugas learn the routes from their cultural communities, like this one in Canada's Cunningham Inlet.

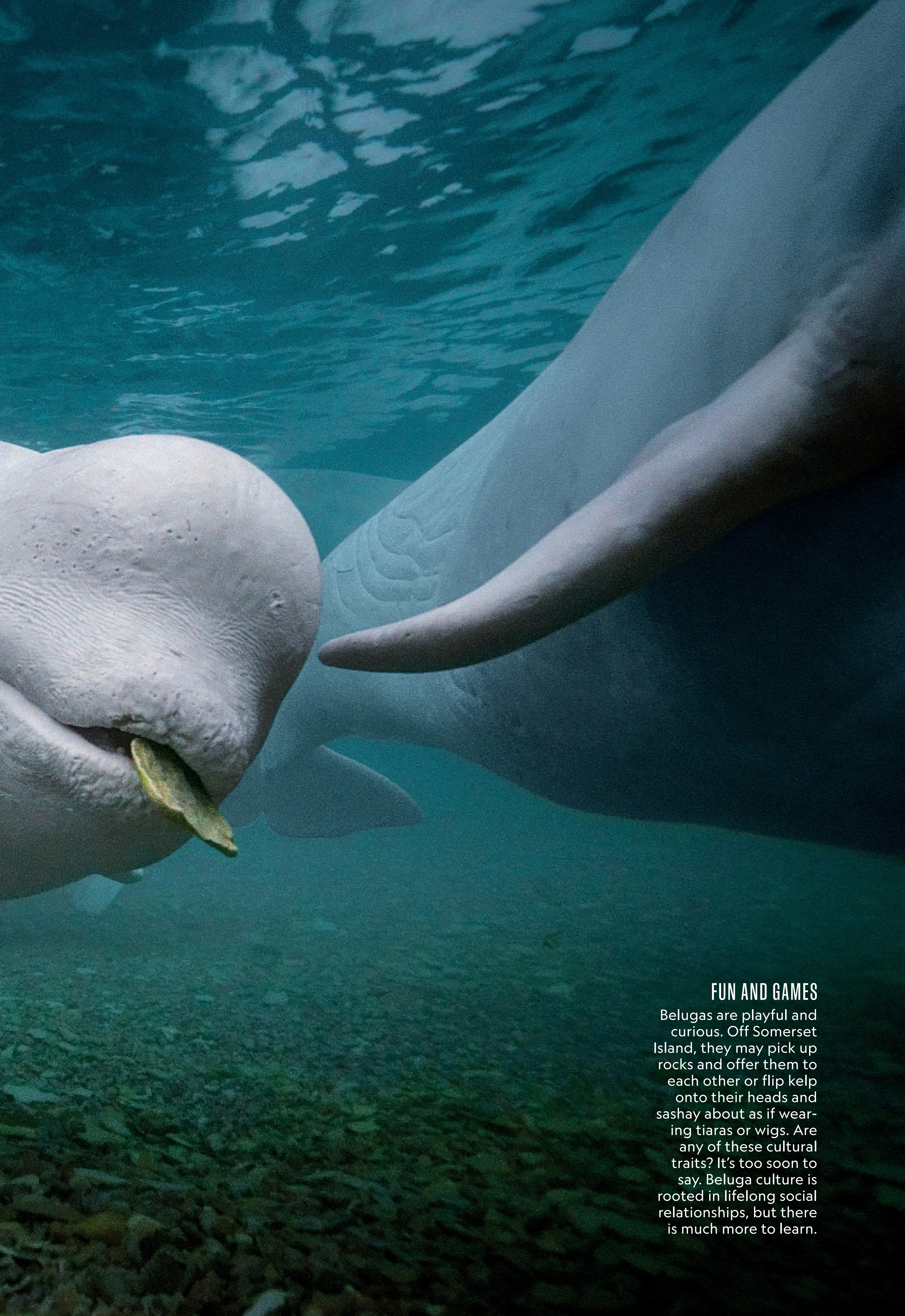
THE WORM

The shallow inlet allows observation of beluga behavior. Some learn to swim with their heads above water, like this adult, or waggle their flukes like the juvenile next to it. Some inch across the bottom, doing "the worm" to slough off old skin.



SAY MY NAME

Like a whale maternity ward, beluga cows and their calves flock to the slightly warmer waters at the mouth of the Cunningham River in Canada's Arctic. Several times, when they were temporarily trapped in river pools by receding tides, scientist Valeria Vergara recorded multiple belugas vocalizing at once. She now suspects they use individual calls, like names, suggesting they broadcast their identities.



FUN AND GAMES

Belugas are playful and curious. Off Somerset Island, they may pick up rocks and offer them to each other or flip kelp onto their heads and sashay about as if wearing tiaras or wigs. Are any of these cultural traits? It's too soon to say. Beluga culture is rooted in lifelong social relationships, but there is much more to learn.

The burbling wail begins to climb until it reaches a pinched-off, airy screech, like a child blowing a conch. Soon the sounds change entirely, becoming dark and melodic, then ethereal and wispy. I hear what sounds like a squeegee stroking glass. A high note ends with a chirp that recalls the tiny squeak that slips from a yawning puppy. A bass croak rolls out like a long, slow burp.

This is the song of a male humpback whale. It was sent to me by Ellen Garland, a colleague of Rendell's at the University of St. Andrews. A few years ago a tune much like this one swept across the South Pacific, igniting a full-blown cultural revolution.

Male humpbacks pick up songs from one another. And male humpbacks are into fresh beats. Like pop culture fanatics, they're always chasing that next sound, eager to find a trendy new tune. The speed with which they adopt new sonic arrangements "is astounding," Garland tells me one morning when I reach her by phone in the United Kingdom. So too is a song's geographic reach. One song can spread across an ocean basin.

Scientists have been studying humpback songs in earnest since at least the 1960s. That's when biologist Roger Payne famously towed a hydrophone behind a sailboat in the dead of night off Bermuda, capturing eerie, echoing moans. Humpbacks trumpet, bark, and groan, and make noises like mewling kittens. But in their basic structure, humpbacks' sophisticated symphonies can be spookily similar to our own.

Humpback songs employ rhyme and rhythm, phrasing and melody. There are themes followed by variations and returns to those original statements. Whales have been around for 50 million years. Before recent decades, there was little possibility that humans and humpbacks had heard each other's melodies. "Yet whales use many of the same laws of composition in their songs that we use in ours," Payne wrote in his book *Among Whales*. A single whale song may last half an hour. A single whale may sing all afternoon.

Garland came to her whale insights by way of the sky. For a college project in her native New Zealand, she'd classified the vocalizations of song thrushes, discovering a talent for acoustic cataloging. Years later she applied her auditory skills to whales.

Humpback songs are part of mating rituals. And researchers had long assumed all humpbacks in an area shared the same song each year. "That's not what we found at all," Garland says. Using spectrograms that transform sound frequencies into pictures, revealing the amplitude and patterns of whale songs, she analyzed years of whale tunes across the South Pacific. She reviewed humpback songs in French Polynesia, then moved toward songs from Australia, some 3,700 miles away.

She noticed something curious. Songs appeared to originate in Australia. They would evolve as whales began to tinker. Like composers, they'd add hiccups or whistles or new verses. But then, like a pop song that suddenly catches fire and takes a hemisphere by storm, this new song would roll from whale to whale across thousands of miles, moving from New Caledonia to Tonga, then a year later to the Cook Islands.

The tune that wound up in French Polynesia would be similar to the song that first appeared in Australia. Despite minor tinkering along the way, the final version was not much different from an acoustic cover of an original hit. Yet it was unrecognizable from the song it was replacing. This new production was as unlike its predecessor "as the Rolling Stones and Justin Bieber," Garland tells me.

Garland was floored. She suspects whales respond to the song's novelty. In the same way hipsters seek out new indie bands, male whales appear to pick up new tunes to stand out from the crowd. But eventually all of the males will abandon their song and switch to the novel one.

That kind of progression once was unexpected.

HOW YOU CAN HELP

Planet Possible
Check out National Geographic's new solutions-oriented initiative: *natgeo.com/planet*. These nonprofits working on whale issues are among those we've supported over the years:

The Dominica Sperm Whale Project
The project's researchers have spent thousands of hours observing sperm whale families in the Caribbean to better understand their unique cultures. *thespermwhaleproject.org*

Whale Trust Maui
Scientists here study natural behavior patterns associated with reproduction and communication, including humpback singing, to develop better protection methods. *whaletrust.org*

Alaska Whale Foundation
Founded in 1996 to study humpback whales in southeast Alaska, AWF now conducts research on an array of marine animals and coastal ecosystems throughout the region. *alaskawhalefoundation.org*

It's a rare moment in the animal kingdom of rapid transformational change—a true cultural revolution. Birds moving into another flock tend to take up calls of their hosts, Garland says. But when a whale hits open-mike night with a hot new number, locals drop their old ballad to belt out a new one. Garland offers an analogy: Imagine moving to a neighboring country where everyone you meet swaps his or her national anthem for yours.

"It is incredibly, incredibly weird," she says.

T

THE BIG QUESTION NOW is whether some of these whale communities will survive long enough for us to understand their cultures. Few know this better than Ford, the Canadian killer whale biologist. As a teenager, he swept popcorn off the floor and fed seals and belugas at the Vancouver Aquarium. He would go on to discover distinct orca dialects before leading West Coast whale research for the Canadian government.

When I ask about resilience during one of our many talks, Ford shares a story. Killer whales travel in matrilineal family pods for life and learn how and what to eat by watching their kin. In 1970, when wild orcas in the region were still being caught for marine parks, wranglers drove five killer whales into a British Columbia cove. Two were taken to a marine park. The remaining three refused to eat the salmon offered by caretakers. One eventually died. Only after 79 days did the survivors start eating fish.

The whales were "caught in this behavioral rut," Ford tells me. The caretakers didn't know killer whales in the Northwest represent three different diets: southern- and northern-resident salmon-eaters; coastal shark-eaters; and Bigg's killer whales, which hunt only marine mammals. Unlike some other cetaceans whose culture offers them flexibility, these killer whales are unwilling or unable to switch food even when options dwindle, much as Norwegian explorer Roald Amundsen beat Robert Falcon Scott, a Brit, to the South Pole by eating his sled dogs, which Scott refused to do. "It's just an example of how ingrained these cultures are," Ford says.

That's partly why, in 2019, more than two dozen scientists, including Ford, Garland, Whiten, and Whitehead, called for a sea change in global conservation. In the journal *Science* they urged the world to incorporate culture into wildlife management decisions. The Convention on Migratory Species already is developing a plan for South American countries to protect sperm whales in the eastern Pacific by focusing on what individual clans require. Such approaches are "essential to maintaining the natural diversity and integrity of Earth's rich ecosystems," the authors argue.

My region is trying, but another culture is in the way: ours.

The United States and Canada already treat the southern and northern fish-eating whales as distinct populations despite their genetic similarities and proximity. The belly-rubbing, head-knocking northern whales aren't the same as the high-flying acrobatic pods that sometimes appear outside Seattle. We recognize that oceans—and humans—need both.

But they face starkly different futures. The number of killer whales in the more rural north has skyrocketed since the 1970s. The southern whales are critically endangered.

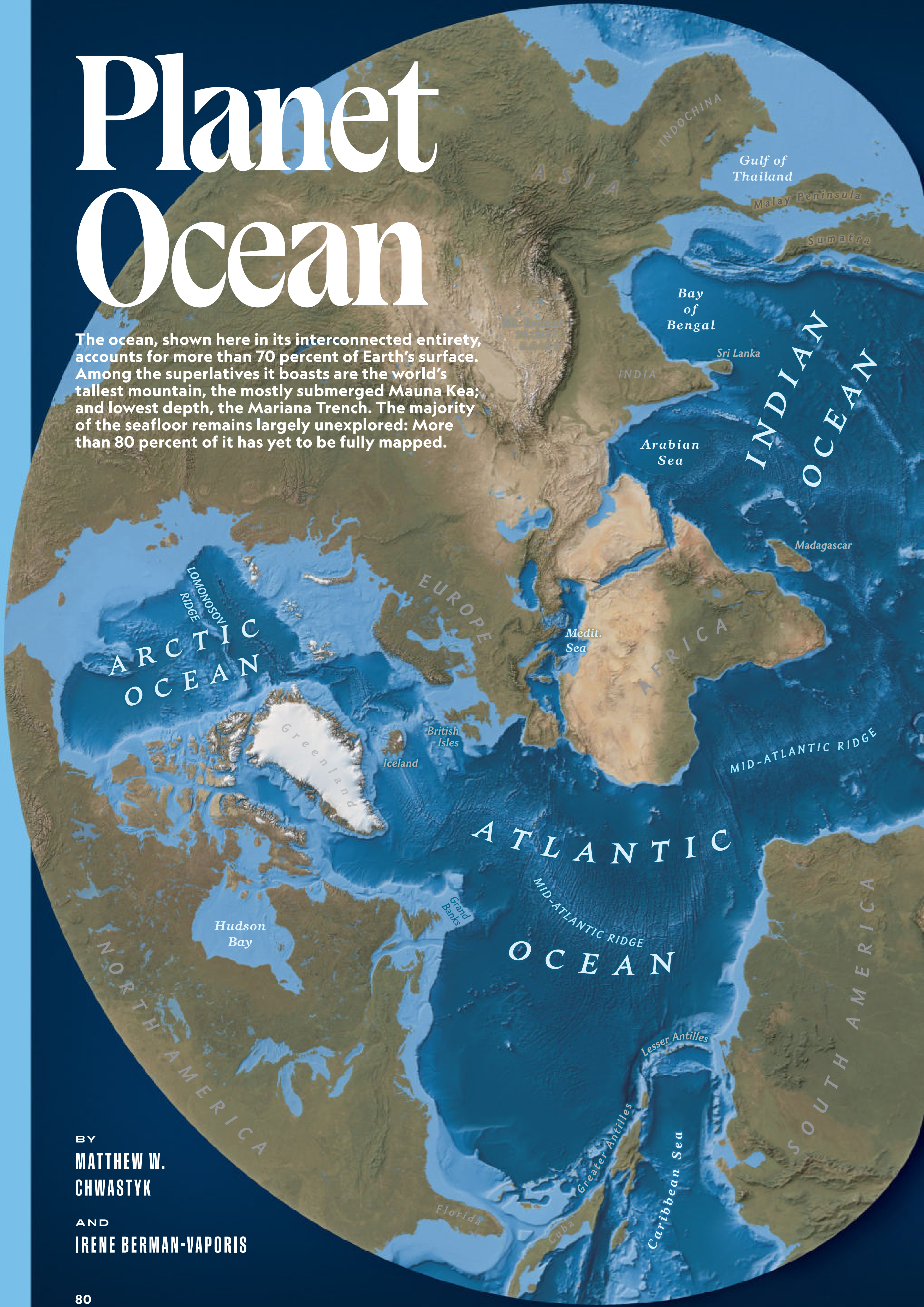
Decimated by culling for marine parks in the 1960s and early '70s, the southern residents now battle noise from boat traffic. Development crowds their shores, dumps silt in their waters, and brings pollution. Toxic chemicals, such as polychlorinated biphenyls (PCBs), have built up in their blubber. All of that is made far worse by a drastic shortage of food as Chinook populations plummet, thanks to years of fishing, dambuilding, more development, and climate change.

These sophisticated alien beings are, quite literally, vanishing before our eyes, not so different from South America's pre-Inca Tiwanaku Empire, which left no written record of its 12th-century collapse. We don't know what might disappear with them. We can't explain why they act as they do or why that's so unlike other whales. But we're at least beginning to acknowledge that what's at stake is rich and important in ways we may not yet fully comprehend. □

Staff writer **Craig Welch** wrote about a cross-country road trip in electric cars for the April 2020 issue. Photographer **Brian Skerry**'s images of mako sharks appeared in the August 2017 issue.

Planet Ocean

The ocean, shown here in its interconnected entirety, accounts for more than 70 percent of Earth's surface. Among the superlatives it boasts are the world's tallest mountain, the mostly submerged Mauna Kea; and lowest depth, the Mariana Trench. The majority of the seafloor remains largely unexplored: More than 80 percent of it has yet to be fully mapped.



BY

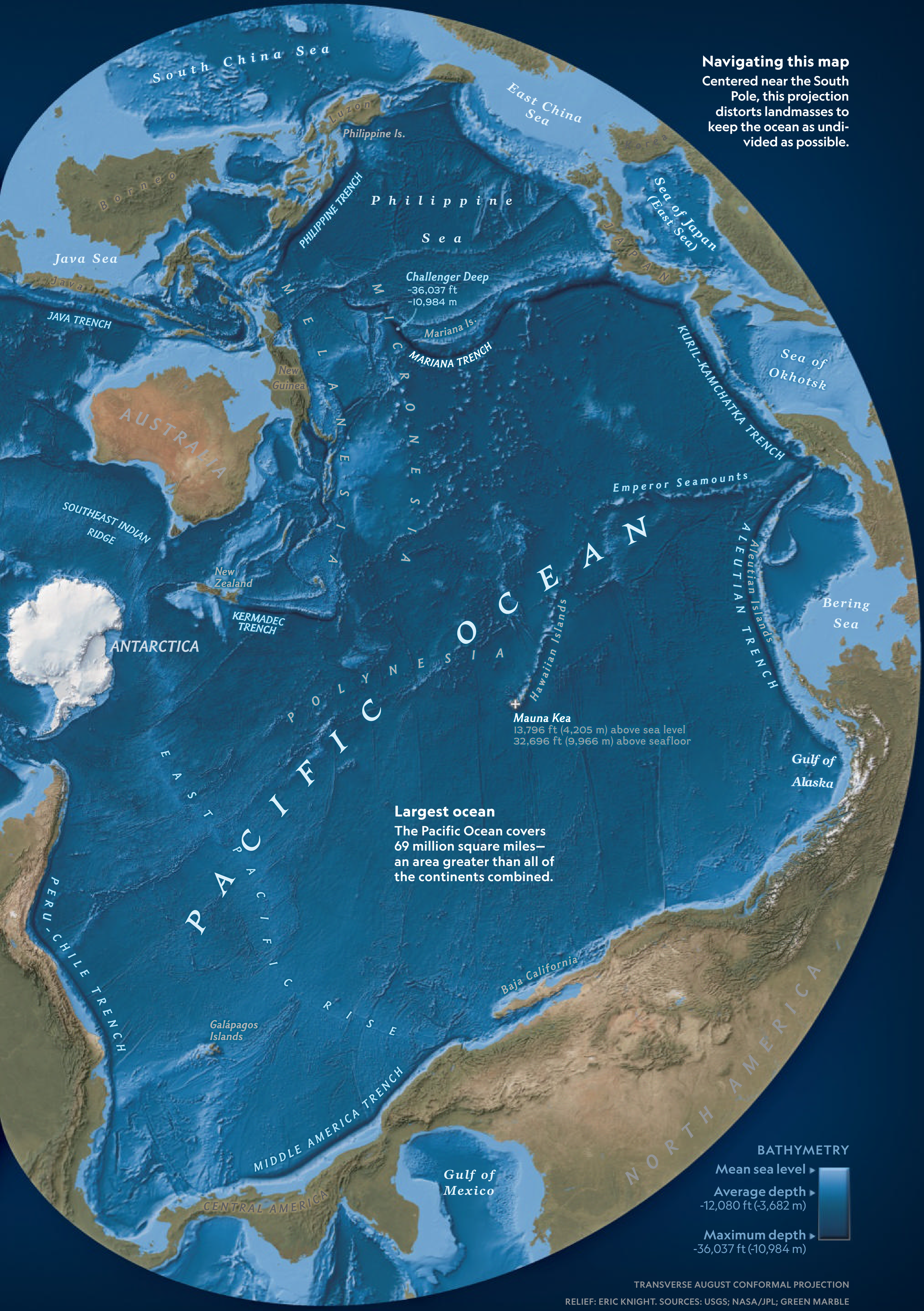
MATTHEW W. CHWASTYK

AND

IRENE BERMAN-VAPORIS

Navigating this map

Centered near the South Pole, this projection distorts landmasses to keep the ocean as undivided as possible.



Largest ocean

The Pacific Ocean covers 69 million square miles—an area greater than all of the continents combined.

BATHYMETRY

Mean sea level ▸

Average depth ▸
-12,080 ft (-3,682 m)

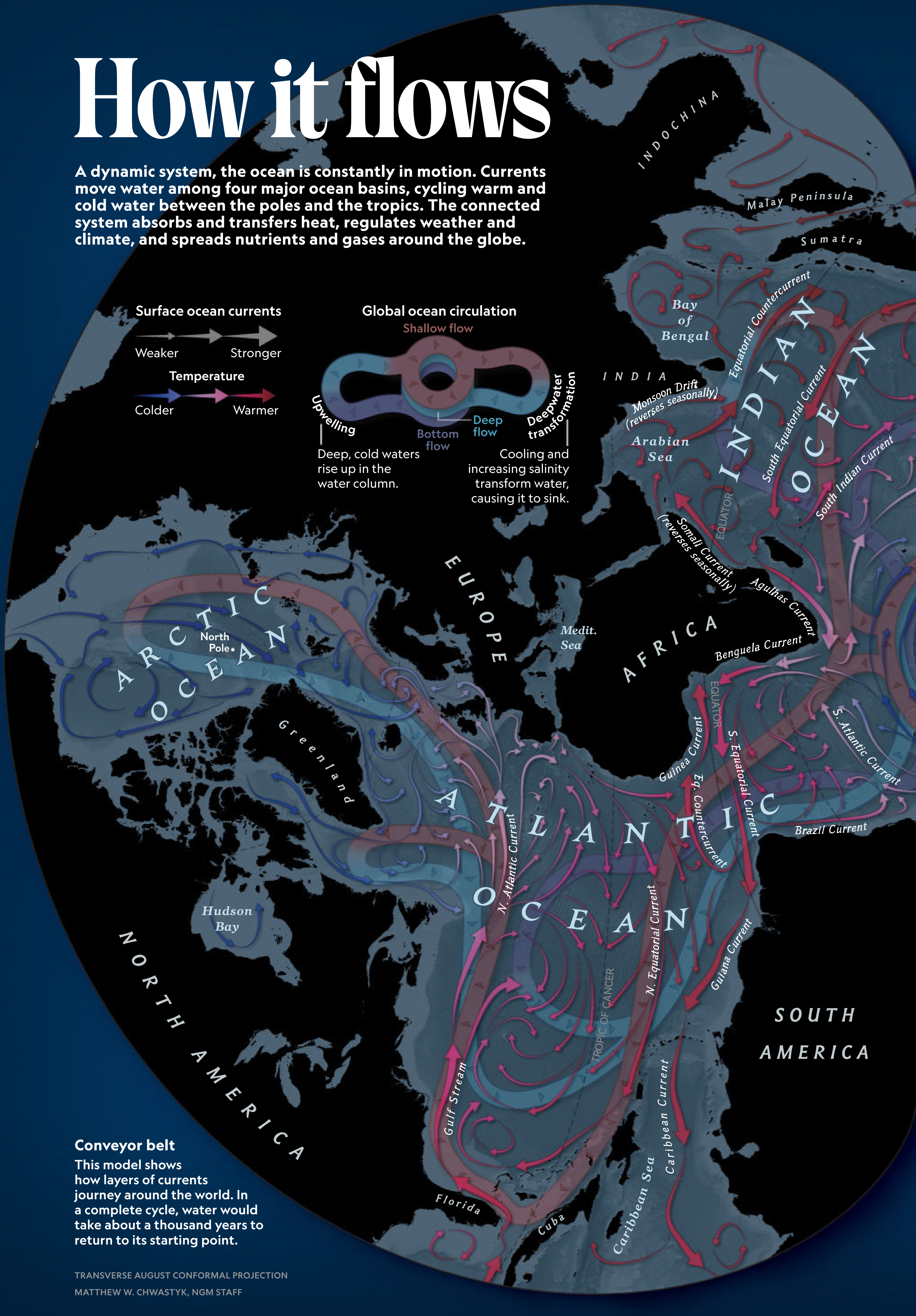
Maximum depth ▸
-36,037 ft (-10,984 m)

TRANSVERSE AUGUST CONFORMAL PROJECTION

RELIEF: ERIC KNIGHT. SOURCES: USGS; NASA/JPL; GREEN MARBLE

How it flows

A dynamic system, the ocean is constantly in motion. Currents move water among four major ocean basins, cycling warm and cold water between the poles and the tropics. The connected system absorbs and transfers heat, regulates weather and climate, and spreads nutrients and gases around the globe.



Deep, cold waters rise up in the water column.

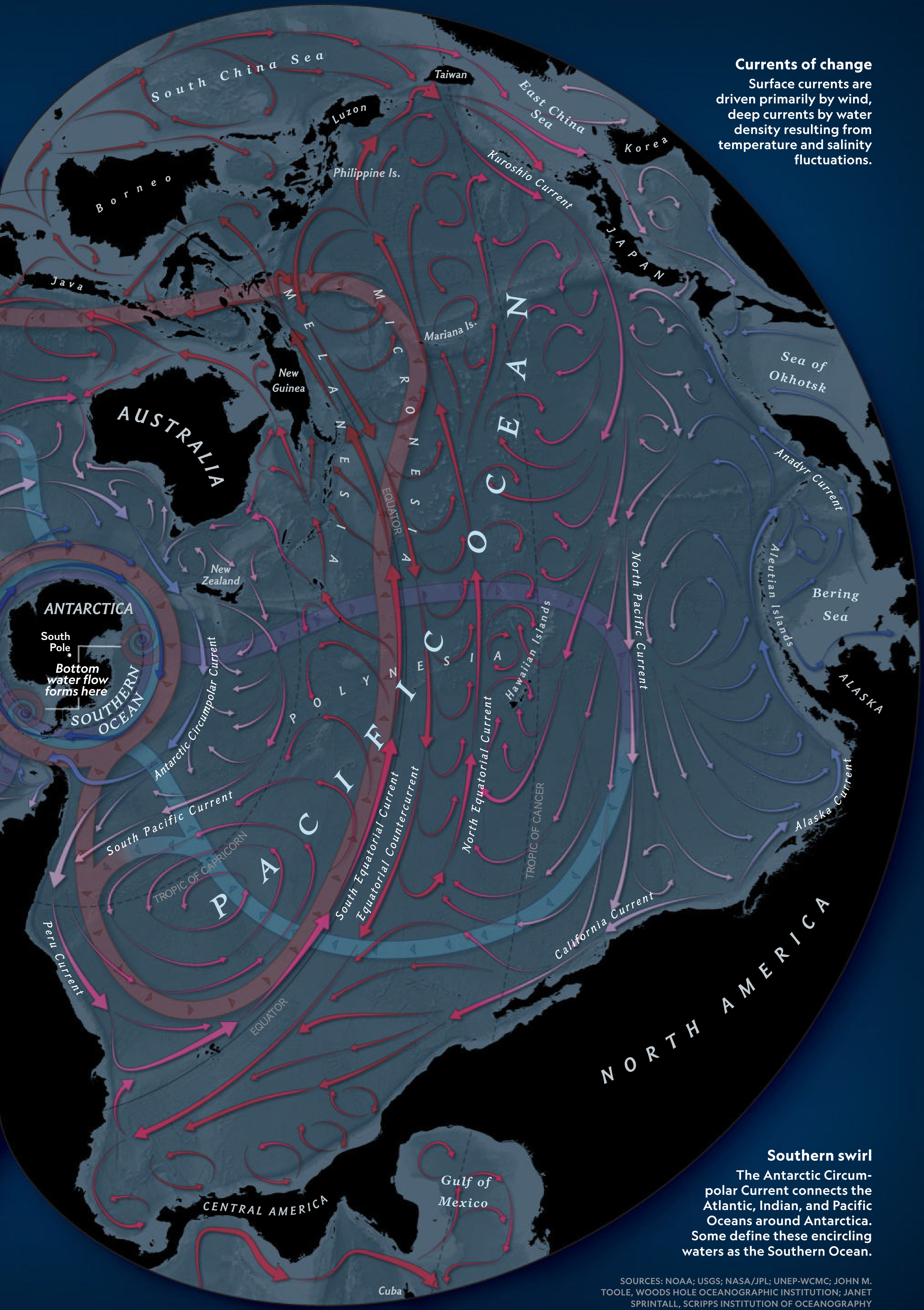
Cooling and increasing salinity transform water, causing it to sink.

Conveyor belt

This model shows how layers of currents journey around the world. In a complete cycle, water would take about a thousand years to return to its starting point.

TRANSVERSE AUGUST CONFORMAL PROJECTION

MATTHEW W. CHWASTYK, NGM STAFF



Currents of change

Surface currents are driven primarily by wind, deep currents by water density resulting from temperature and salinity fluctuations.

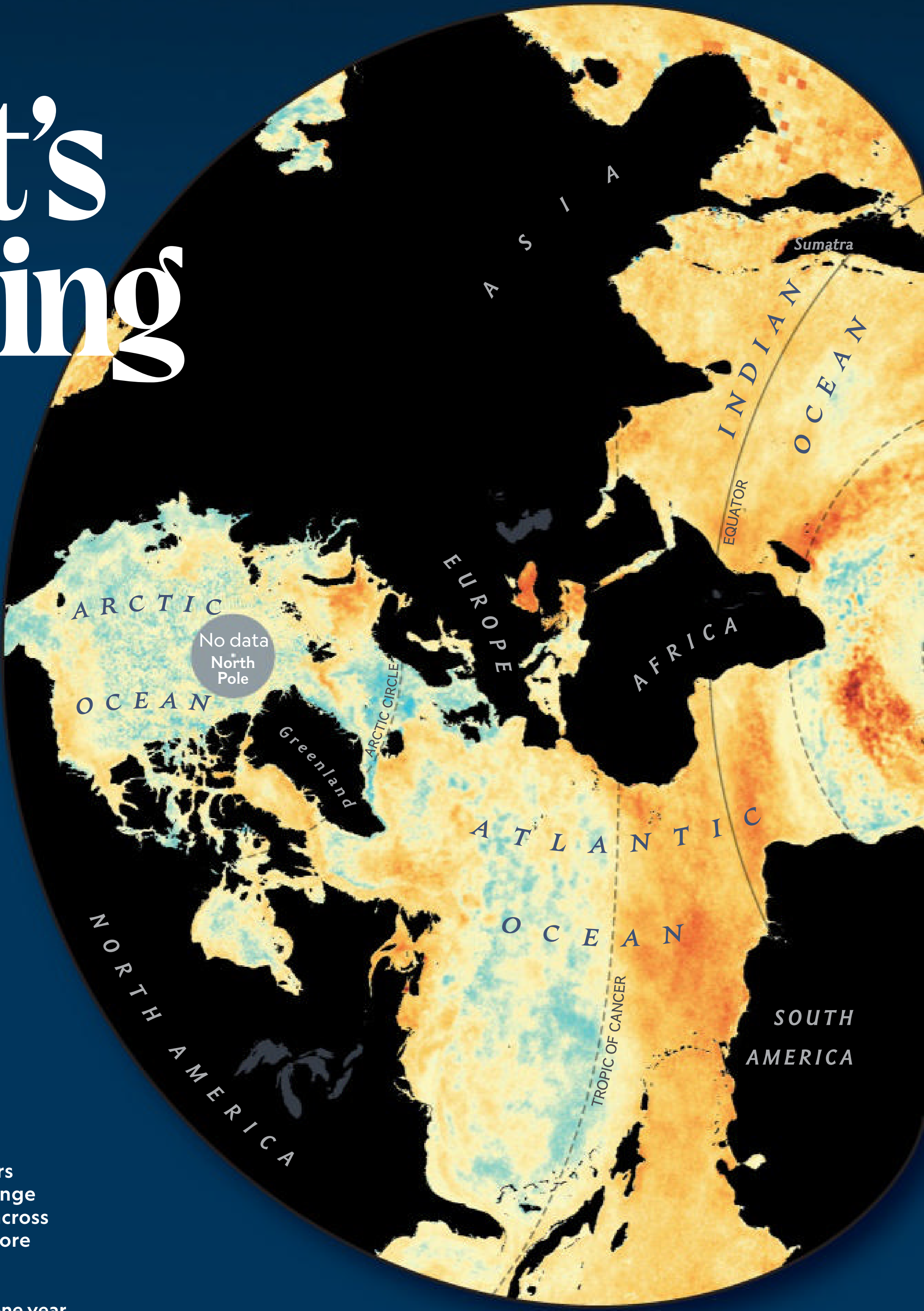
Southern swirl

The Antarctic Circumpolar Current connects the Atlantic, Indian, and Pacific Oceans around Antarctica. Some define these encircling waters as the Southern Ocean.

SOURCES: NOAA; USGS; NASA/JPL; UNEP-WCMC; JOHN M. TOOLE, WOODS HOLE OCEANOGRAPHIC INSTITUTION; JANET SPRINTALL, SCRIPPS INSTITUTION OF OCEANOGRAPHY

How it's changing

Climate change, commercial fishing, pollution, shipping: Nearly 60 percent of the ocean is under cumulative stress, at an accelerating pace, from human activities. Easing these pressures is crucial to the ocean's survival.



LEADING THREATS

Scientists examined 14 human stressors on 20 marine ecosystems. Climate change pressures caused significant impacts across all of them, with intertidal and nearshore ecosystems the most vulnerable.

Cumulative impact on ecosystems over one year

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

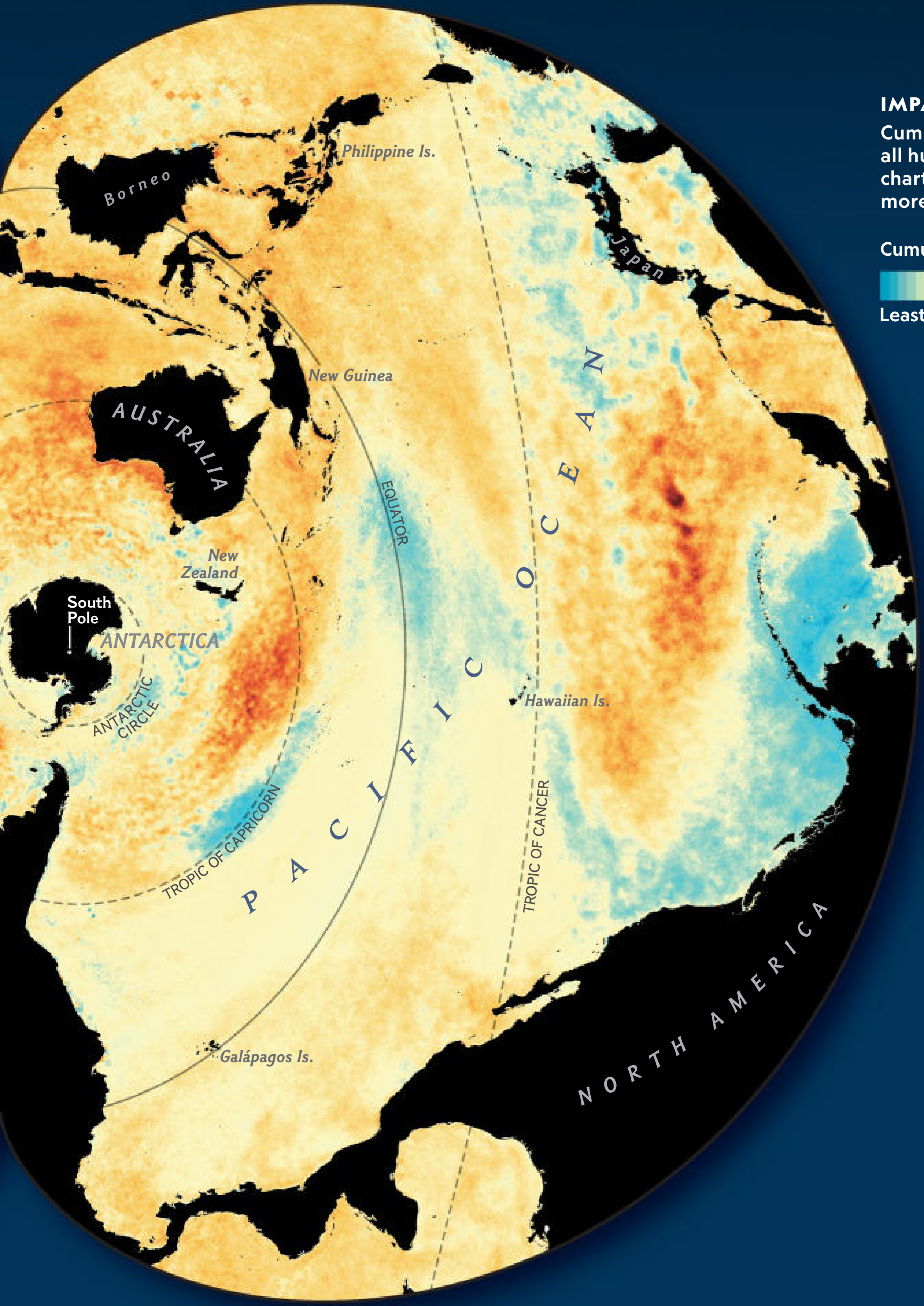
Least Greatest

INTERTIDAL ECOSYSTEMS

Places affected by tides are particularly at risk from sea-level rise and encroaching coastal development.

	STRESSOR	Description	ROCKY INTERTIDAL	BEACH	MUD-FLATS	SALT MARSH	MAN-GROVE
	TEMPERATURE	Frequency of extreme sea-surface temperatures	🟥	🟩	🟨	🟨	🟧
	OCEAN ACIDIFICATION	Acidity caused by increasing carbon dioxide	🟥	🟦	🟥	🟥	🟧
	SEA-LEVEL RISE	Extent of average sea-level anomalies	🟥	🟧	🟧	🟥	🟫
	SHIPPING	Intensity of global shipping activity	🟦	🟧	🟧	🟨	🟨
	NUTRIENT POLLUTION	Intensity of land-based fertilizers	🟨	🟦	🟨	🟨	🟥
	ORGANIC CHEMICAL POLLUTION	Intensity of land-based organic chemical pollution	🟩	🟦	🟨	🟩	🟨
	DIRECT HUMAN	Human disturbances, such as habitat trampling or noise	🟥	🟥	🟥	🟧	🟫
	LIGHT POLLUTION	Impact of light radiance on marine habitats	🟩	🟨	🟩	🟨	🟦
FISHING	DESTRUCTIVE SEABED	Commercial fishing on the seafloor (using trawls, dredges)	🟦	🟦	🟦	🟦	🟦
	SEABED (HIGH)	Nondestructive methods (pots, traps) with high bycatch	🟦	🟦	🟦	🟦	🟦
	SEABED (LOW)	Nondestructive methods (hook and line) with low bycatch	🟦	🟦	🟦	🟦	🟦
	SURFACE (HIGH)	Surface fishing (longline) with high bycatch	🟦	🟦	🟦	🟦	🟦
	SURFACE (LOW)	Surface fishing (purse seine nets) with low bycatch	🟦	🟦	🟦	🟦	🟦
	ARTISANAL	Small-scale, nonindustrial fishing	🟦	🟦	🟦	🟦	🟨

IRENE BERMAN-VAPORIS, MATTHEW W. CHWASTYK, AND ALBERTO LUCAS LÓPEZ, NGM STAFF
SOURCES: BENJAMIN HALPERN AND COLLEAGUES, NATIONAL CENTER FOR ECOLOGICAL ANALYSIS AND SYNTHESIS, UCSB



IMPACT OVER TIME

Cumulative ocean change stemming from all human stressors (detailed in bottom chart) is shown on this map, reflecting more than a decade of recorded data.

Cumulative impact

Least Greatest

Heating up

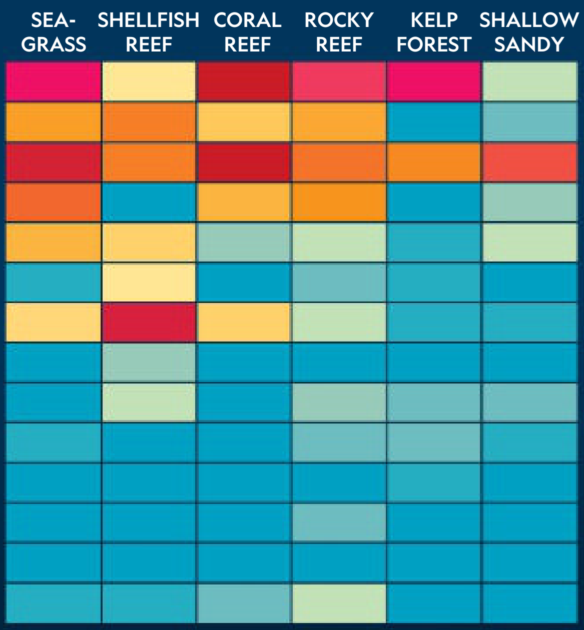
The ocean stores more than 90 percent of the world's excess heat. Last year the heat in the upper layers of the ocean was the highest on record.

Taking action

To combat the growing pressures on the ocean, a group of 14 countries* recently pledged to sustainably manage 100 percent of their waters.

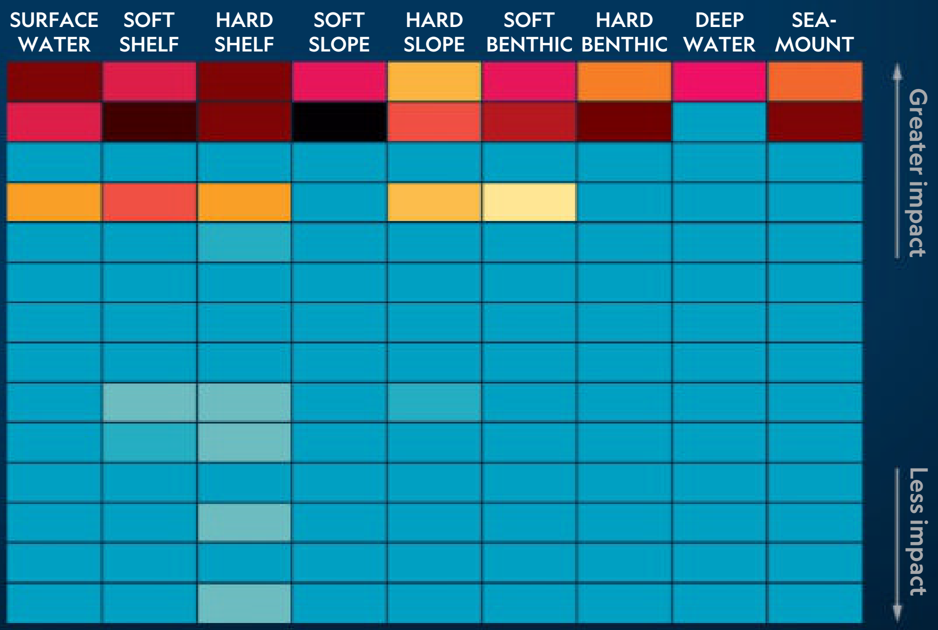
NEARSHORE ECOSYSTEMS

Shellfish and rocky reefs are among the nearshore areas vulnerable to dredging, trawling, and other fishing practices.



OFFSHORE ECOSYSTEMS

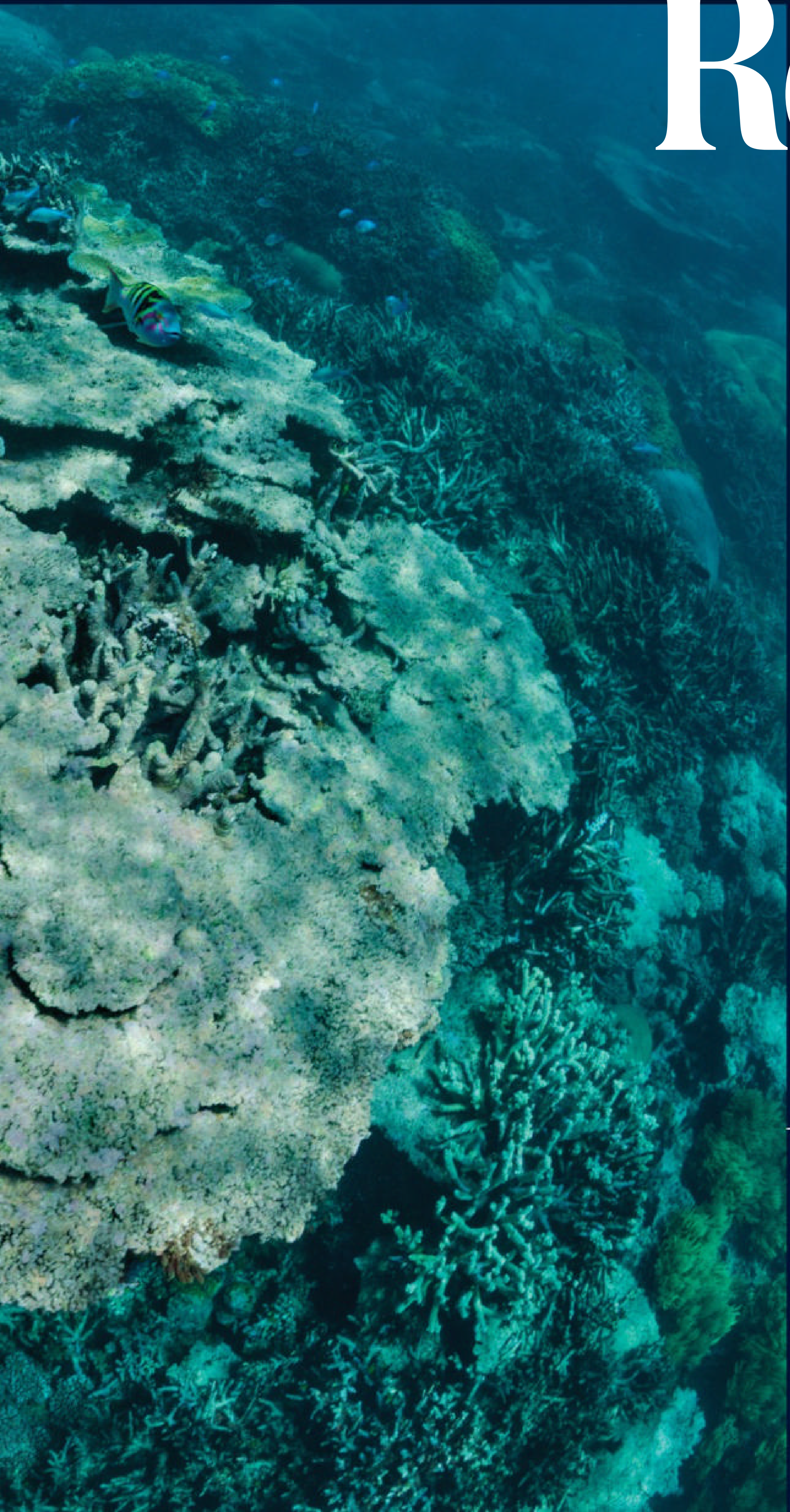
Many species in the deep sea are accustomed to stable conditions. Even small changes in ocean acidity can wreak havoc on species living around underwater mountains called seamounts.



*COUNTRIES INCLUDE AUSTRALIA, CANADA, CHILE, FIJI, GHANA, INDONESIA, JAMAICA, JAPAN, KENYA, MEXICO, NAMIBIA, NORWAY, PALAU, AND PORTUGAL.

AS CLIMATE CHANGE WARMS THE OCEANS AND KILLS SOME OF THE WORLD'S MOST SPECTACULAR CORAL, SCIENTISTS ARE SCRAMBLING TO PROTECT VULNERABLE AREAS AND DEVELOP HARDIER SPECIES.

Rescuing Reefs



Opal Reef, part of Australia's Great Barrier Reef, was damaged when ocean temperatures spiked in 2016 and 2017. "The once colorful coral was a gray ruin and all but dead—a skeletal statue created by climate change," says David Doubilet. To document how climate change affects reefs, he and Jennifer Hayes returned to some of the most stunning corals they'd previously photographed.

BY

JENNIFER S. HOLLAND

PHOTOGRAPHS BY

DAVID DOUBILET AND JENNIFER HAYES

A cuttlefish patrols a lively oasis in the Great Barrier Reef that survived being stressed by high water temperatures. Scientists look for such corals to study what makes them resilient and to propagate them for use in restoring reefs. “In nature, resilience is variable,” says coral ecologist Charlie Veron. “That’s always a joy to see.”

In the Florida Keys, 18-year-old John Ziska, who has volunteered with SCUBAnauts International since 2015, tends staghorn coral cuttings for Mote Marine Laboratory's restoration efforts. In the last 10 years, divers have "planted" nearly 110,000 fragments on Florida's ailing reefs.

T

THE DIVERS SHRIEKED into their regulators, arms and legs flailing in delight. It was August 2020. Thirteen feet down on a reef in the Florida Keys, marine biologist Hanna Koch and her colleagues from the Mote Marine Laboratory & Aquarium had been hovering, waiting. Just before midnight, in a silent explosion from coral all along the reef, tiny pinkish orange bundles of sperm and eggs began to rise, speckling the sea with a pointillist eruption of life.

The team's happy dance set off electric blue sparkles from the bioluminescent organisms in the sea around them. "It looked like we'd created our own fireworks," Koch says. "It was beautiful."

This sudden flurry is how many reef-building corals typically reproduce—usually once a year on a summer night a few days after a full moon. Cued by the lunar cycle, water temperature, and day length, coral species across Florida's reefs simultaneously release trillions of sperm and millions of eggs; it's a frenzy that boosts genetic diversity and ensures some small percentage of eggs will be fertilized, settle onto the reef as larvae, and seed the next generation.

The National Geographic Society, committed to illuminating and protecting the wonder of our world, has funded Explorer David Doubilet since 2012. This is the 50th anniversary of his first assignment as a *National Geographic* photographer. Doubilet and Jennifer Hayes seek to document both the beauty and the devastation in our oceans.

ILLUSTRATION BY JOE MCKENDRY

But this was no ordinary spawning event. These mountainous star corals—*Orbicella faveolata,* listed as threatened under the Endangered Species Act—were cultivated and "planted" in 2015 by Mote scientists as part of a reef restoration effort. The corals survived a bleaching event that year, a Category 4 hurricane in 2017, and a disease outbreak two years later, demonstrating heartening resilience. They reached reproductive maturity years faster than their wild counterparts, and they became the first restored boulder-forming corals to spawn at sea.

It was a welcome milestone for scientists hustling to save corals from the devastating effects of climate change and other human-driven threats. Of the more than 800 known species of reef-building corals, the International Union for Conservation of Nature classifies more than a quarter as vulnerable, endangered, or critically endangered, and warns that as temperatures rise, so too does the extinction risk for corals.

NEARLY 40 YEARS AGO Peter Harrison, a marine ecologist at Australia's Southern Cross University, witnessed the first recorded large-scale coral bleaching event. Diving off Magnetic Island in the Great Barrier Reef, he was stunned by the scene before him. "The reef was a patchwork of healthy corals and badly bleached white corals, like the beginnings of a ghost city," he says. Just months before, the same site had bustled with tropical life in Crayola colors.

"Many of the hundreds of corals that I'd carefully tagged and monitored ultimately died," he says. “It was shocking and made me aware of just how fragile these corals really are.”

Coral exists symbiotically with photosynthetic algae, which live in its tissues and provide essential nourishment (and coloration). But high temperatures and other stresses can turn algae toxic. When this occurs, the algae may die or be ejected by the coral, a process known as bleaching because the coral’s clear tissue and white calcium carbonate skeleton are exposed. If the coral can’t reestablish its bond with algae, it will starve or succumb to disease.

The devastation Harrison saw in 1982 was repeated on many other Pacific Ocean reefs that year and the next. In 1997 and 1998 the phenomenon went global, killing some 16 percent of the world’s corals. With rising temperatures, pollution, disease, increased ocean acidity, invasive species, and other hazards, Harrison’s ghost cities are sprawling.

Scientists surmise that about four decades ago severe bleaching occurred roughly every 25 years, giving corals time to recover. But bleaching events are coming faster now—about every six years—and in some places soon they could begin to happen annually.

“The absolute key is dealing with global warming,” says marine biologist Terry Hughes of Australia’s James Cook University. “No matter how much we clean up the water, the reefs will succumb.” In 2016, a record-hot year in a string of them, 91 percent of the reefs that comprise the Great Barrier Reef bleached.

A REEF IS FULL OF MUSIC. And motion. Clicks and taps, squeaks and gurgles accompany the shimmying of soft corals, the quivering of shrimp, the nibbling of fish, the skittering of crabs. Moray eels poke from hollows like open-mouthed puppets, reef sharks battle for a bite, curious cuttlefish loiter, then bolt. With thickets of elkhorn corals, and boulder corals like massive cakes iced in pinks and greens, their tiers decorated with lacy sea fans, tube worms, and feather dusters, reefs are fantastical—a Seussian stage set for a recurring daily drama. From every nook, cartoonish critters wave fins or claws or tentacles, each defending its little place in the world.

A dozen years ago I spent 15 “pinch me” days among them, diving the Great Barrier Reef with photographers David Doubilet and Jennifer Hayes. The article I wrote for this magazine celebrated the reef and sounded the alarm: We could lose this extraordinary place. As a journalist with a background in conservation biology, I fretted over failing ecosystems; as a diver and lover of the sea, I feared a much deeper loss. So when I saw the more recent photos of the reefs where we had dived—some now algae-strangled rubble fields—I imagined the stillness and silence, and I cried.

Despite that devastation, the Great Barrier Reef remains a colossus—some 3,000 separate reefs strung along 1,400 miles of Australia’s northeast coastline—and a rarity: Tropical, shallow-water coral reef complexes cover less than one percent of the seafloor. The death of even a single reef has devastating effects; these ecosystems support at least a quarter of all ocean life. Reefs are also vital for human populations, buffering coastlines from storms, sustaining fisheries, and luring tourists. Experts estimate reefs directly benefit more than half a billion people, contributing tens of billions of dollars a year to the global economy through tourism alone. Meanwhile, the value of coral reefs to the human psyche—by experiencing one, or just knowing they exist—is surely incalculable.

That so many reefs are suffering in the heat, then, is immensely significant, but the effects differ. “Climate change moves as a uniform blanket across the Earth, but there is plenty of variation in the details,” says coral ecologist Charlie Veron, former chief scientist at the Australian Institute of Marine Science. “Coral bleaching is patchy, and local weather conditions are key: You may have monsoon clouds protecting the

> **‘What’s happening to reefs is a crisis of governance—of water quality, of fisheries, and especially of greenhouse gases—and there’s work to be done in all three realms.’**
>
> —TERRY HUGHES, MARINE BIOLOGIST

reef over here, but over there it's blue skies and the sun is hammering the water." That variability makes it especially difficult to design interventions in a broad way, Veron says.

For more than 20 years the National Oceanic and Atmospheric Administration has used satellite and on-site data as well as modeling to forecast when and where bleaching is likely to occur, "giving coastal managers some lead time, a chance to ramp up protective efforts," says Mark Eakin, the agency's Coral Reef Watch coordinator. This early warning system has led some resource managers to limit access in vulnerable reef areas, remove rare corals proactively, and experiment with installing artificial shading.

Such "emergency" strategies aren't cheap, and they aren't long-term solutions. They're also useless where coral has already died. So scientists also are trying to rebuild reefs. Helpfully, although corals are animals, they can be grown much like plants: Collect cuttings, raise them in nurseries, graft the more mature organisms onto degraded reefs, and kick-start new life.

For decades ecologists have been honing this strategy for fast-growing branching corals. But until recently, few ocean farmers tried cultivating the real building blocks of a reef—such as boulder and brain corals, slow-growing giants that can live for centuries and take decades to reach reproductive maturity. Then came a breakthrough: Mote scientists discovered that "microfragments" sawed off these corals act a bit like wounded skin, growing extremely quickly—some 10 times faster than larger cuttings. Grown side by side in lab aquariums, polyps from the same colony will fuse, reducing the time needed to reach reproductive size. Raised this way, some species that typically take a decade or more to mature have begun spawning in just a few years.

Even the best tended garden isn't immune to bad weather, and many nursery-grown branching corals eventually have succumbed to heat. So it's critical, says Mote senior biologist Erinn Muller, to focus on corals with high heat tolerance. Muller is also studying whether there's a link between temperature and a disease called stony coral tissue loss, which first appeared in the Florida Keys in 2014 and now has affected nearly every part of the 360-mile-long barrier reef. "Disease is a chronic problem for corals, so we screen for disease tolerance as well as heat tolerance and ramp up reproduction of those most likely to survive both in the coming decades," she says. "That way we integrate resilience right into our restoration pipeline."

Mote's strategies also support reef recovery beyond Florida's waters. Raising Coral Costa Rica—a team led by local and American coral reef ecologists—is both farming branching species and microfragmenting boulder species to revive ancient reefs in Golfo Dulce. These corals, some of them thousands of years old, are of particular interest: With the gulf fed by four rivers and flushed by tides, they are exposed to quick fluctuations in temperature, acidity, and salinity—making them well equipped to handle changing conditions. Their genes, and those of corals living in similarly fickle conditions, could hold clues for bolstering resilience elsewhere.

O

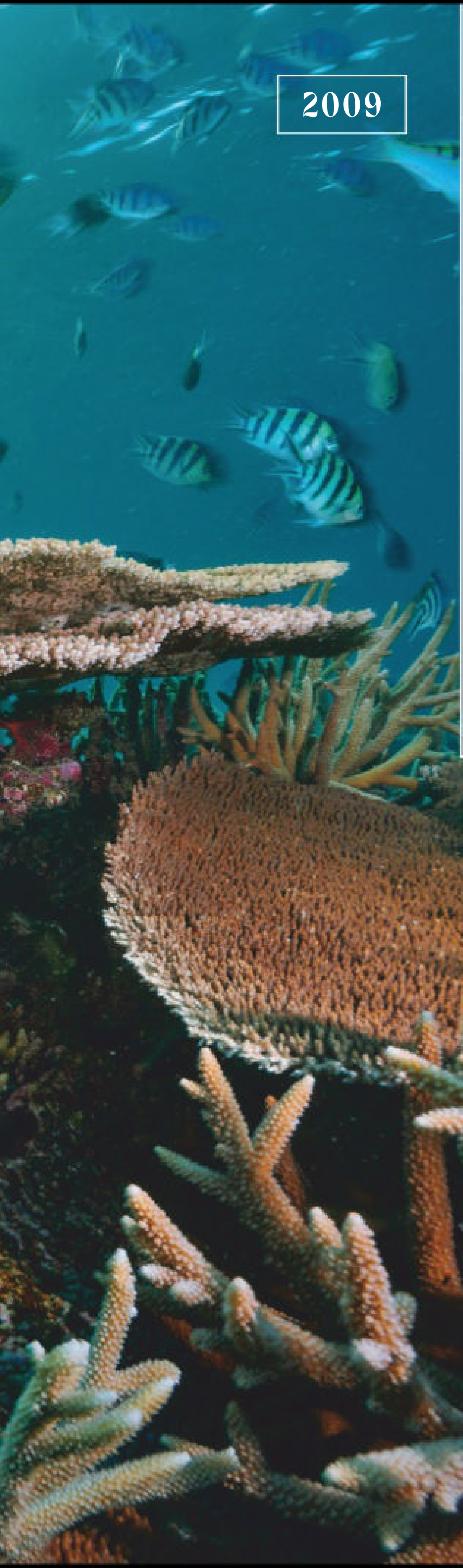
ON THE OTHER SIDE of the globe, Harrison knows that no matter how genetically outstanding a coral's parents, any single larva has only about a one-in-a-million chance of surviving. He wants to improve those odds dramatically. "Larvae have limited control over where they go," he says. The vast majority drift away, and if they do eventually bump into suitable substrate, he notes, there's "a wall of mouths waiting to eat them."

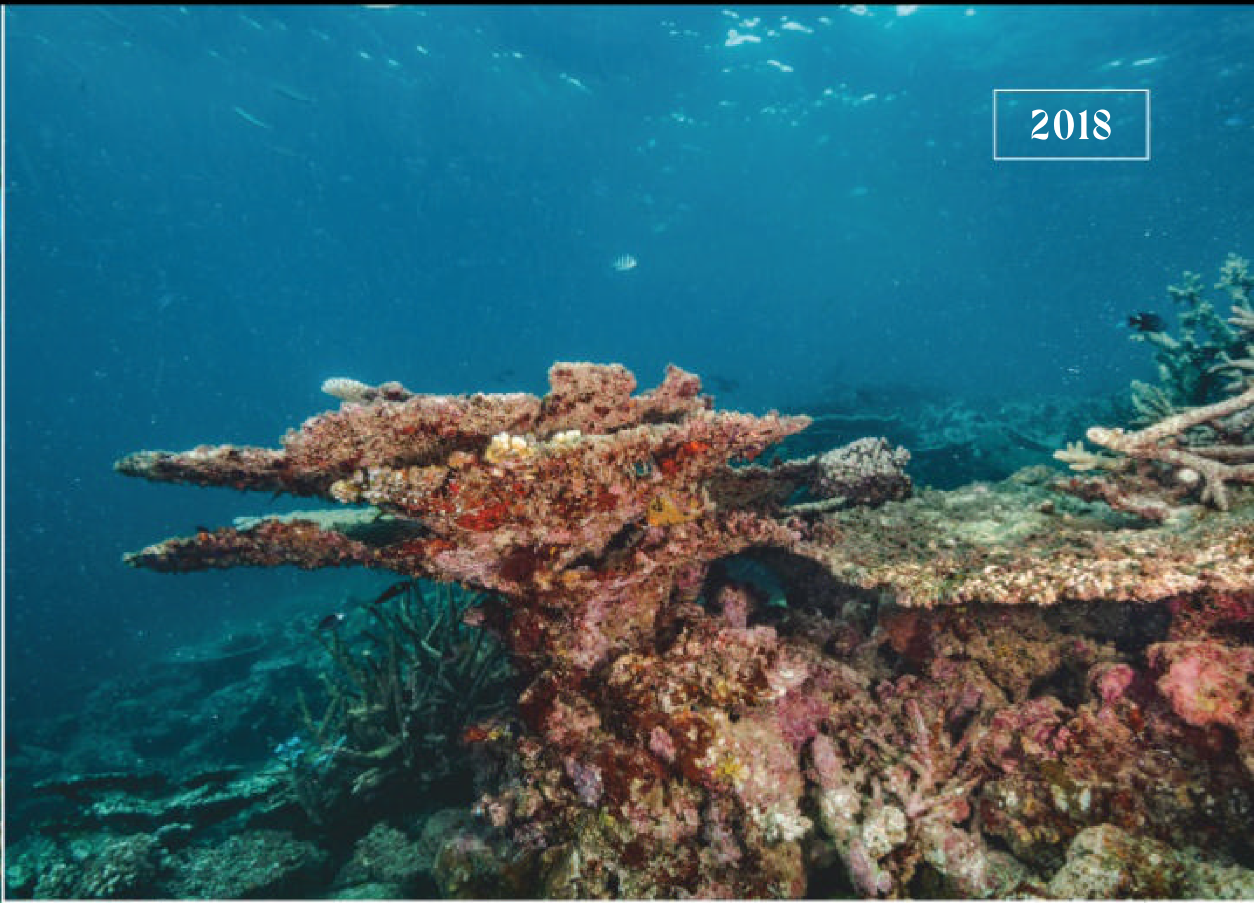
So Harrison's teams scoop up slicks of eggs and sperm released by corals that have survived bleaching and proven their heat tolerance. Amassing the gametes in mesh enclosures near the ocean surface promotes fertilization and larval formation; those offspring can then be drizzled over damaged reefs. Harrison is testing two distribution methods: remote-controlled "LarvalBots" that squirt larvae onto reefs and ceramic plugs with larvae attached that can be stuck into gaps in the reef.

Targeted larval settlement has proven effective on research plots in the Philippines and on the Great Barrier Reef, but Harrison knows he needs to scale way up, spreading billions of larvae over miles of seafloor to make a difference.

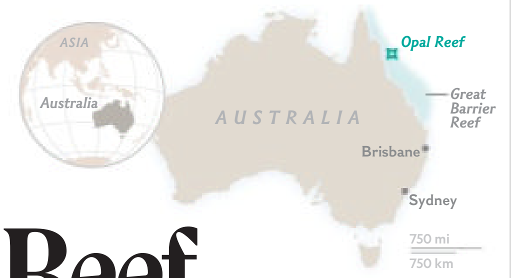
The spawning events

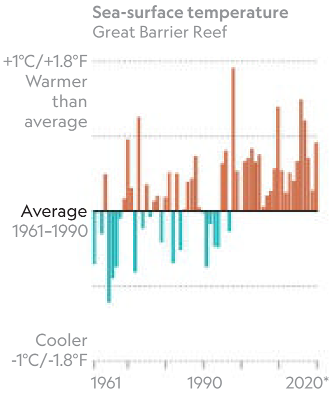
(Continued on page 106)





Great Barrier Reef



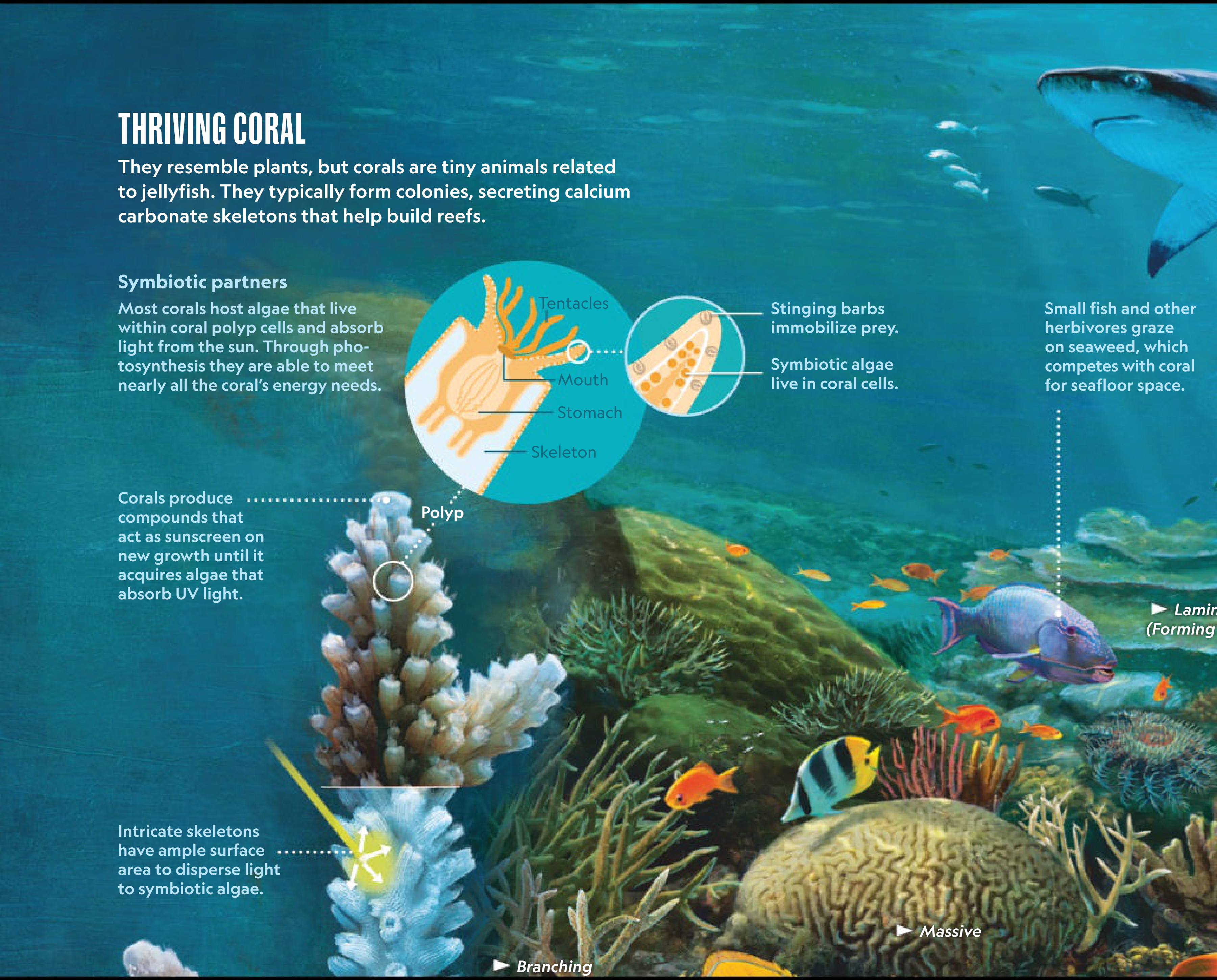


On Opal Reef, staghorn and plate corals were thriving when Doubilet and Hayes dived there in 2009. Nine years later, they found the scene inert. Stressed-out corals had ejected the symbiotic algae that help color and nourish them, causing them to bleach and eventually die. Many of the reef's other residents departed for healthier habitats. "As startling as the destruction was the silence," says Hayes, recalling their return visit. A reef can revive after bleaching, but multiple stresses in succession hinder recovery. Since the mid-1990s, the Great Barrier Reef has lost more than half of its coral. Adaptable species—those able to tolerate warmer waters and other threats—and human interventions will decide the future of this natural wonder.

*THROUGH NOVEMBER 2020. NGM ART. SOURCE: NOAA

THRIVING CORAL

They resemble plants, but corals are tiny animals related to jellyfish. They typically form colonies, secreting calcium carbonate skeletons that help build reefs.



Symbiotic partners

Most corals host algae that live within coral polyp cells and absorb light from the sun. Through photosynthesis they are able to meet nearly all the coral's energy needs.

Stinging barbs immobilize prey.

Symbiotic algae live in coral cells.

Small fish and other herbivores graze on seaweed, which competes with coral for seafloor space.

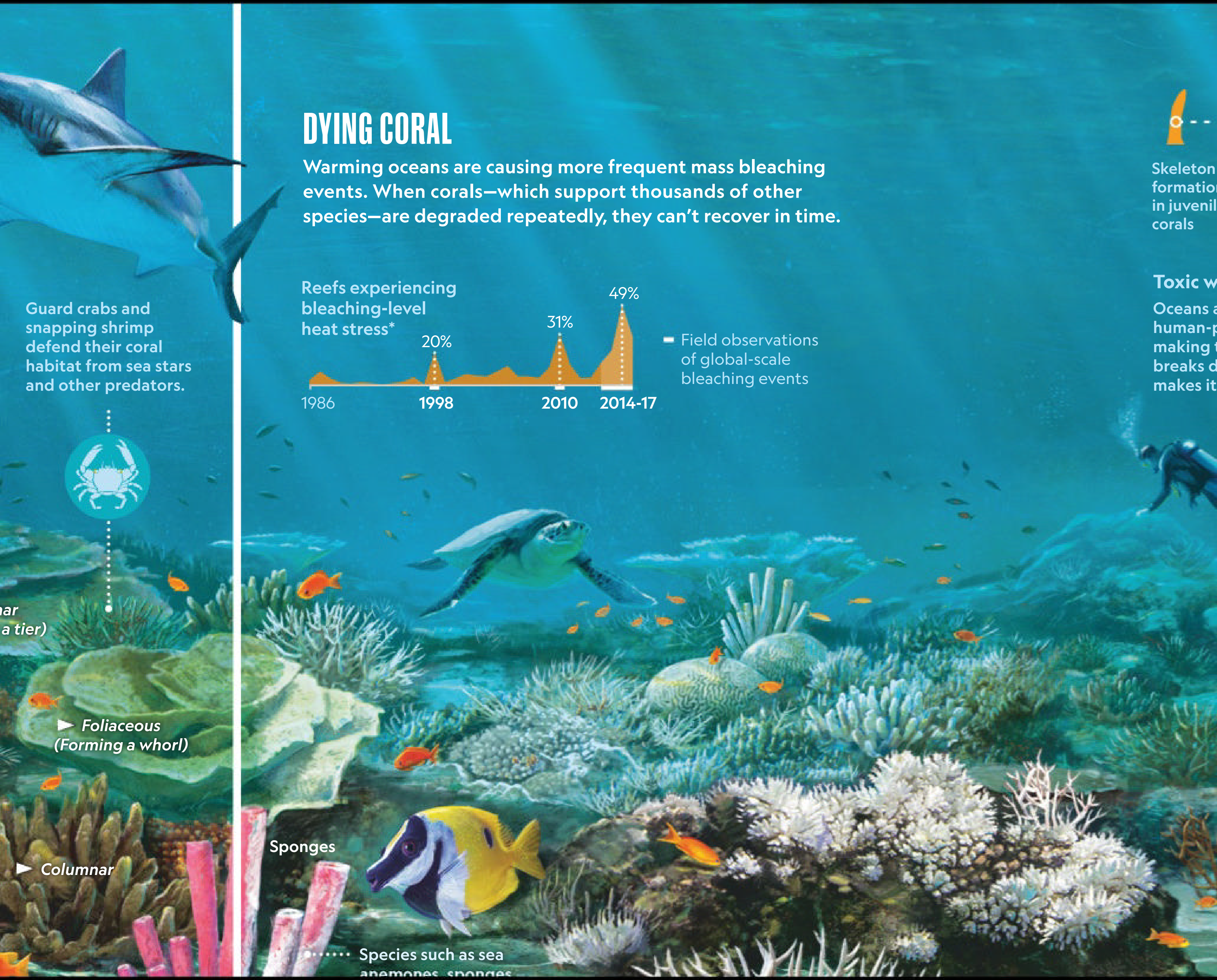
Corals produce compounds that act as sunscreen on new growth until it acquires algae that absorb UV light.

Intricate skeletons have ample surface area to disperse light to symbiotic algae.

Guard crabs and snapping shrimp defend their coral habitat from sea stars and other predators.

DYING CORAL

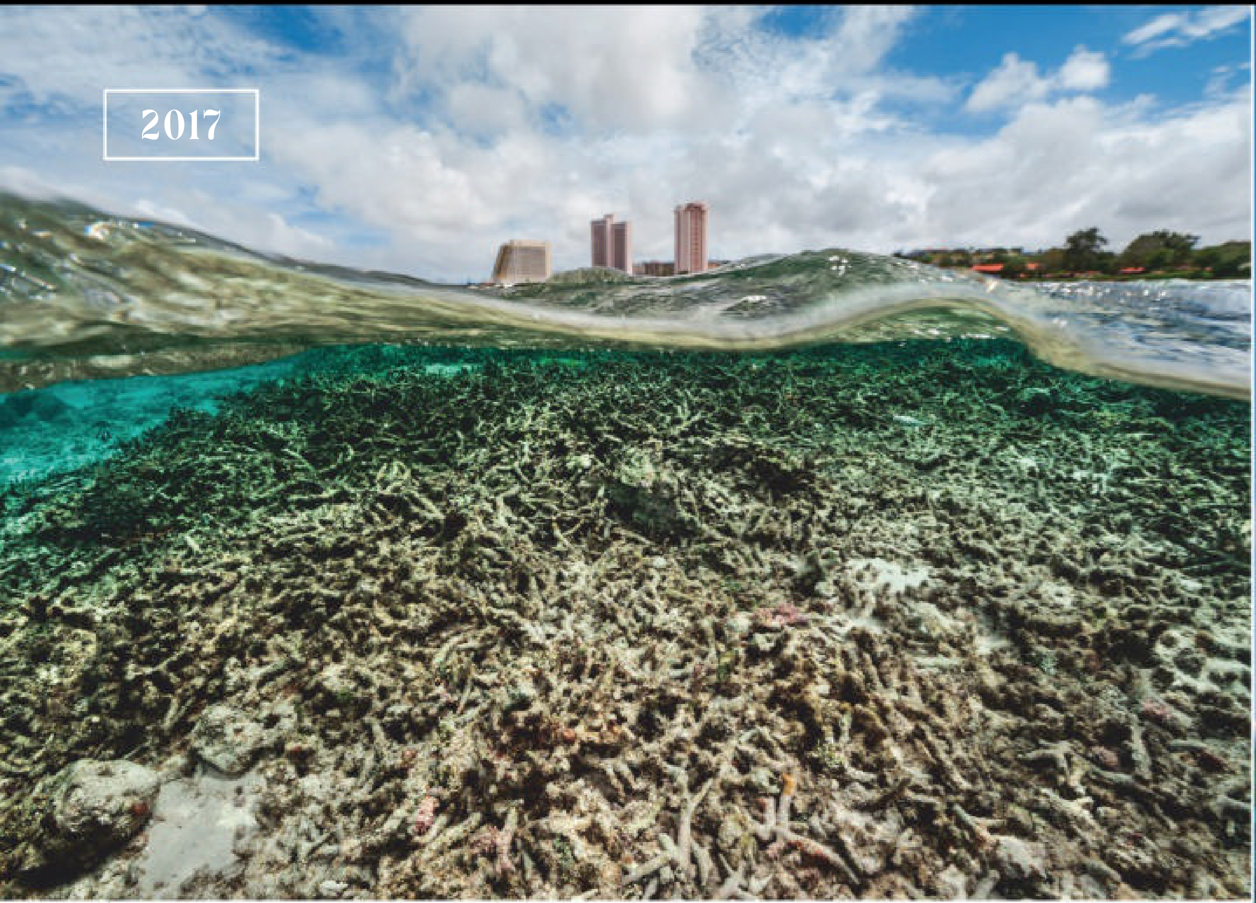
Warming oceans are causing more frequent mass bleaching events. When corals—which support thousands of other species—are degraded repeatedly, they can't recover in time.

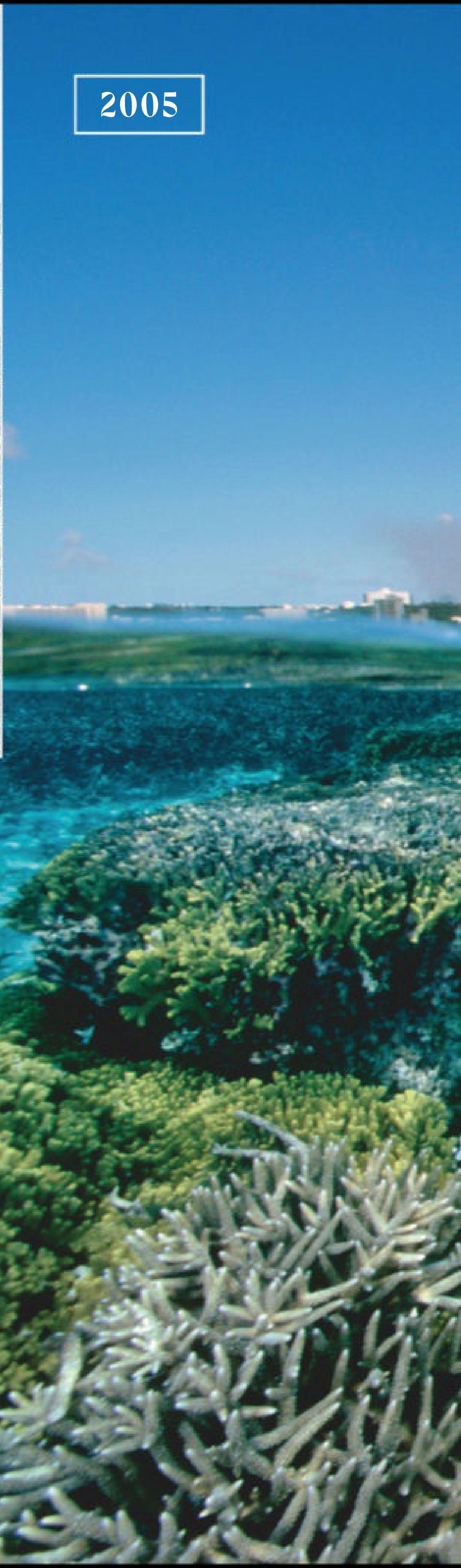

Reefs experiencing bleaching-level heat stress*
20%
31%
49%
1986
1998
2010
2014-17
▬ Field observations of global-scale bleaching events
nar
a tier)
► Foliaceous (Forming a whorl)
► Columnar
Sponges
Species such as sea
anemones, sponges

Skeleton formatio in juvenil corals

Toxic w

Oceans a human-p making t breaks d makes it

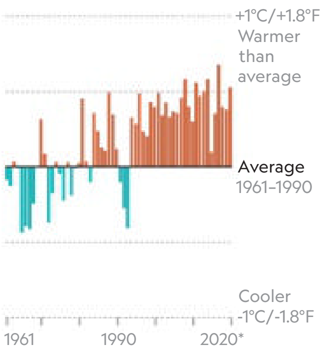




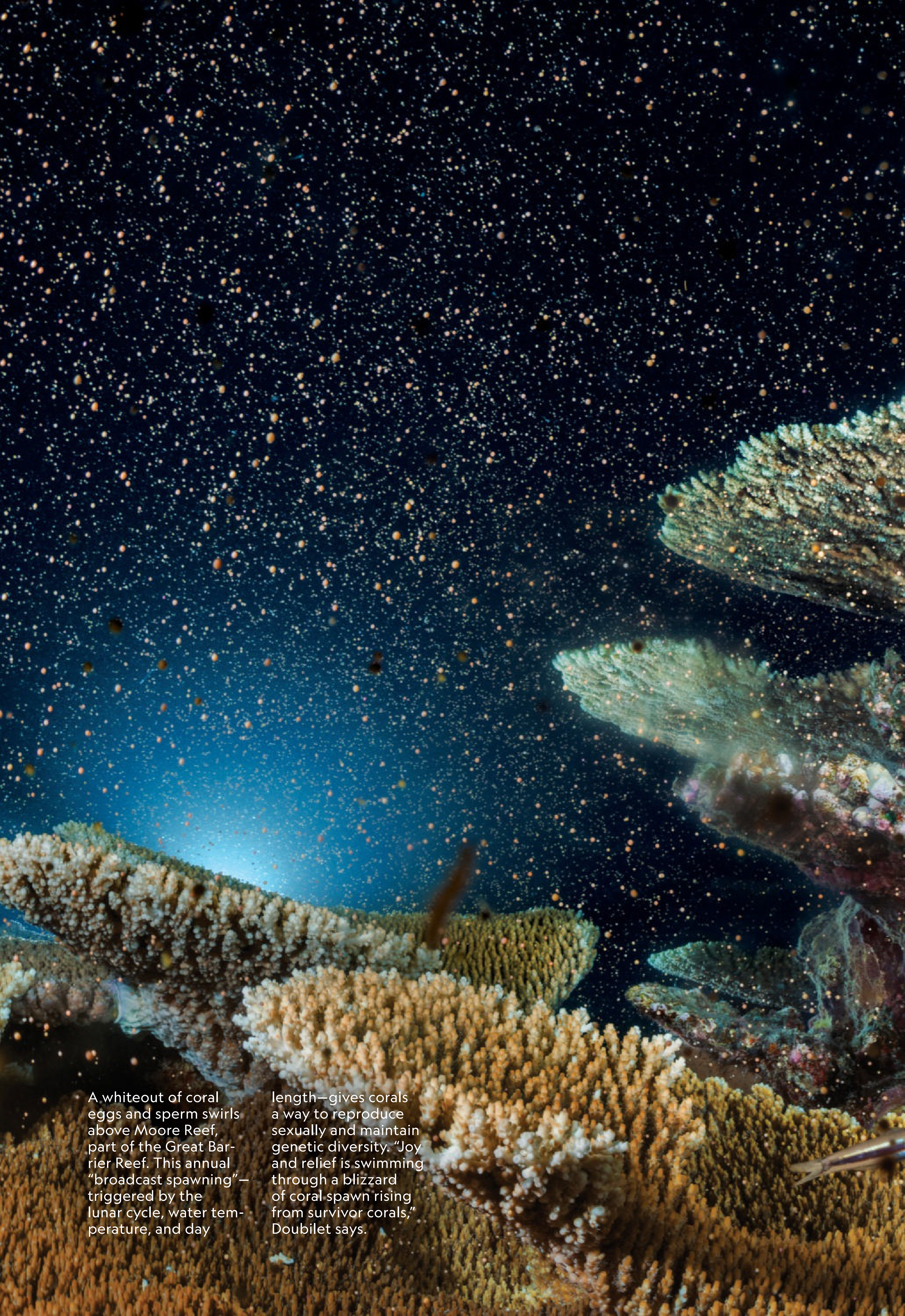
Tumon Bay, Guam

Between the visits Doubilet and Hayes made to Tumon Bay, robust corals turned to bleached rubble. The bay suffered years of elevated sea temperatures, destructive low-tide exposures, and disease outbreaks. From 2013 to 2017, nearly 60 percent of the staghorn communities—whose thickets provide habitat for fish and invertebrates—died. One key species vanished completely. The Micronesian bay, with its shallow, nearshore coral communities, was designated a marine preserve in 1997 and is a lure for tourists and locals. "It's been very difficult to watch," says coral ecologist Laurie Raymundo of the University of Guam, "especially as corals would start to recover, only to be hammered again a few months later."

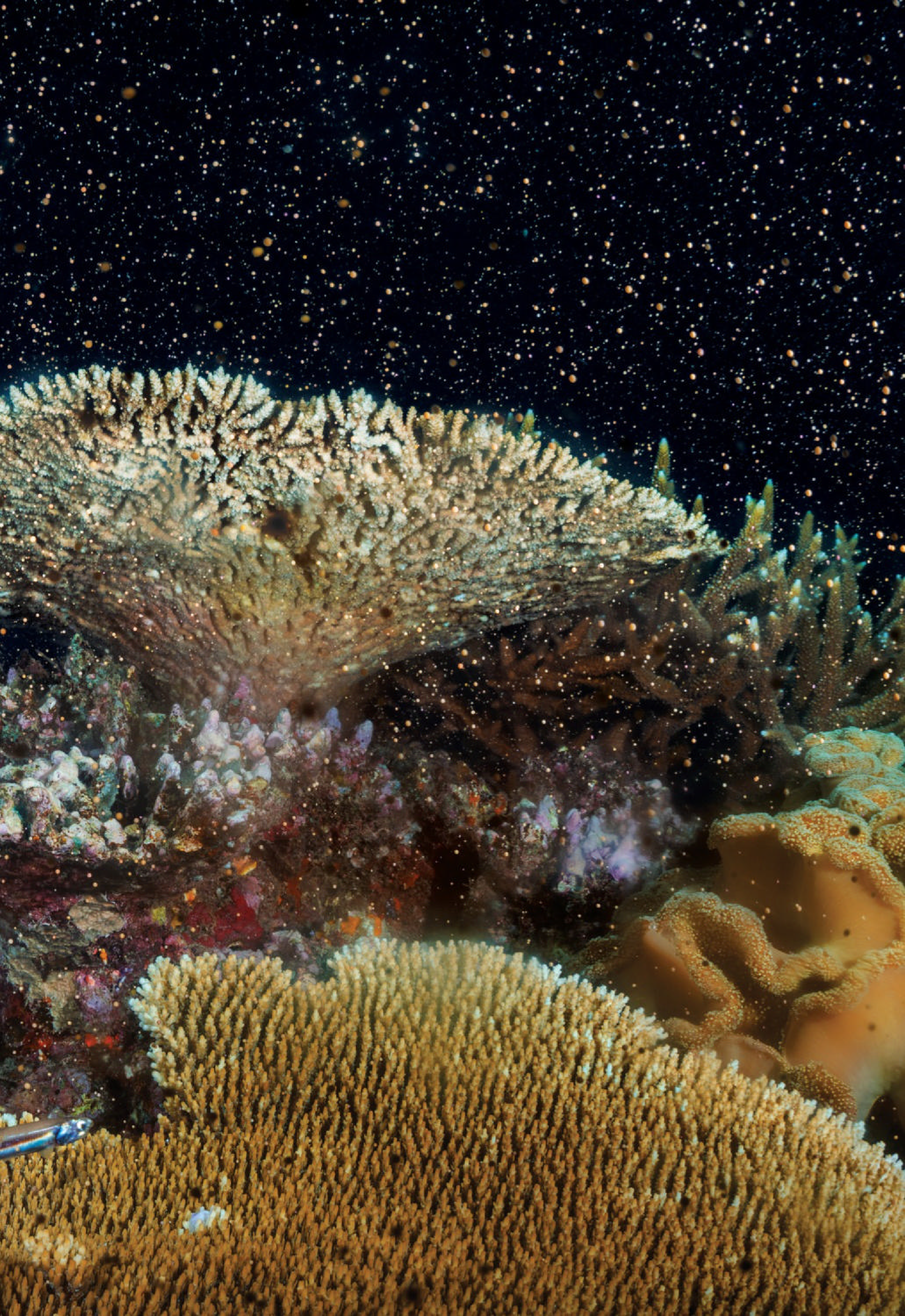
Sea-surface temperature
Guam



*THROUGH NOVEMBER 2020. NGM ART. SOURCE: NOAA



A whiteout of coral eggs and sperm swirls above Moore Reef, part of the Great Barrier Reef. This annual "broadcast spawning"—triggered by the lunar cycle, water temperature, and day length—gives corals a way to reproduce sexually and maintain genetic diversity. "Joy and relief is swimming through a blizzard of coral spawn rising from survivor corals," Doubilet says.



Marine ecologist Peter Harrison of Australia's Southern Cross University prepares a collection net for the coming coral spawn at Moore Reef. Captured eggs and sperm stay in nursery pools in the sea until they form larvae. Harrison will release them over damaged reefs he's trying to restore. This part of the reef survived the bleaching events in 2016 and 2017 that struck the Great Barrier Reef, meaning corals here may have genes that help them tolerate higher temperatures.

at which Harrison pilfers gametes are one of nature's ways of maintaining strong genetic diversity—as eggs and sperm from different parents mingle. But as reef health declines, fewer corals are spawning successfully. After the 2016 and 2017 bleaching events on the Great Barrier Reef, Hughes and colleagues found that larval colonization had dropped 89 percent.

In a lab at the Australian Institute of Marine Science, geneticist Madeleine van Oppen is giving a push to the natural adaptations that could reduce such losses. By teasing out genes related to heat management in algae and bacteria that live in corals, she says, "we are starting to have a good understanding of these intimate associations and to make use of them." By exposing this lab-grown algae to stepwise temperature bumps over years, she lets natural selection and random mutation do the work of boosting the algae's heat tolerance—but on a fast track. Corals that accept these experimentally evolved algal partners have proven less prone to bleaching. Van Oppen also plans to "lab evolve" the bacteria that live in coral microbiomes.

"If we could inoculate coral with lab-grown algae and bacteria that can help neutralize heat stress," she says, "we see the potential to increase thermal bleaching tolerance in the wild."

The institute's scientists are also creating hybrids, crossing corals adapted to warmer waters with cool-water ones of the same species to see if heat tolerance is passed to the offspring. The initial results are promising. "And we are creating hybrids between species, which can

have enhanced climate resilience compared to their purebred counterparts," van Oppen says.

ENCOURAGINGLY, in some instances corals already are doing the job themselves: Scientists working on reefs around the world's largest atoll—Kiritimati in the central Pacific—discovered corals that were recovering from bleaching *during* a heat wave. They did it by taking in naturally heat-tolerant algae.

These comeback corals, however, weren't in crisis from other human-caused stresses when they bleached; those that had been stressed previously did not recover as well, illustrating the devastating impact of a one-two punch. Still, it's a hopeful sign that scientists hadn't seen in the wild.

Reefs worldwide are battered, having absorbed, on average, more than one degree Celsius of warming. "And they're still there," Hughes says. "The mix of corals has changed. It's very different from five years ago, but that's a source of resilience."

He doubts, though, that the animals can survive two- to three-degree warming, and he worries we're putting too much faith in reviving reefs. "Restoration is something of a distraction. The urgent need is to deal with the root reasons," he says. "What's happening to reefs is a crisis of governance—of water quality, of fisheries, and especially of greenhouse gases—and there's work to be done in all three realms."

Meanwhile, as global temperatures trend up, some scientists have taken to prepping—stashing hard corals in "living biobanks" to conserve as much diversity as possible. A holding facility in Sarasota, Florida, is already accepting U.S. specimens, while the nonprofit Great Barrier Reef Legacy and its partners have established the Living Coral Biobank in Australia, where a seaside "ark" will house the more than 800 hard-coral species from around the world.

"This is something we can do right now: Collect every species and tag them and keep them alive indefinitely, for genetic studies and, if possible, to repopulate the oceans with species extinct in the wild sometime in the future," says Veron, one of the biobank's founders. "It's up to us to use every tool we have to keep reefs alive. My belief is, we can't not do this." □

Jennifer S. Holland is a science writer and longtime contributor to the magazine. **David Doubilet** and **Jennifer Hayes** plan to work with Indonesian scientists to explore Coral Triangle conservation efforts.

HOW YOU CAN HELP

If you visit a coral reef, choose dive operations that protect reefs by practices such as tying up to a mooring buoy rather than anchoring, which can cause damage to reefs.

When swimming or diving on a reef, don't touch the coral and don't disturb the other marine life.

Consider covering up with a long-sleeved shirt or a rash guard to minimize sunscreen use, and look for reef-friendly sunscreens that are less harmful to marine life.

Avoid buying souvenirs or jewelry made from coral or any other sea creature.

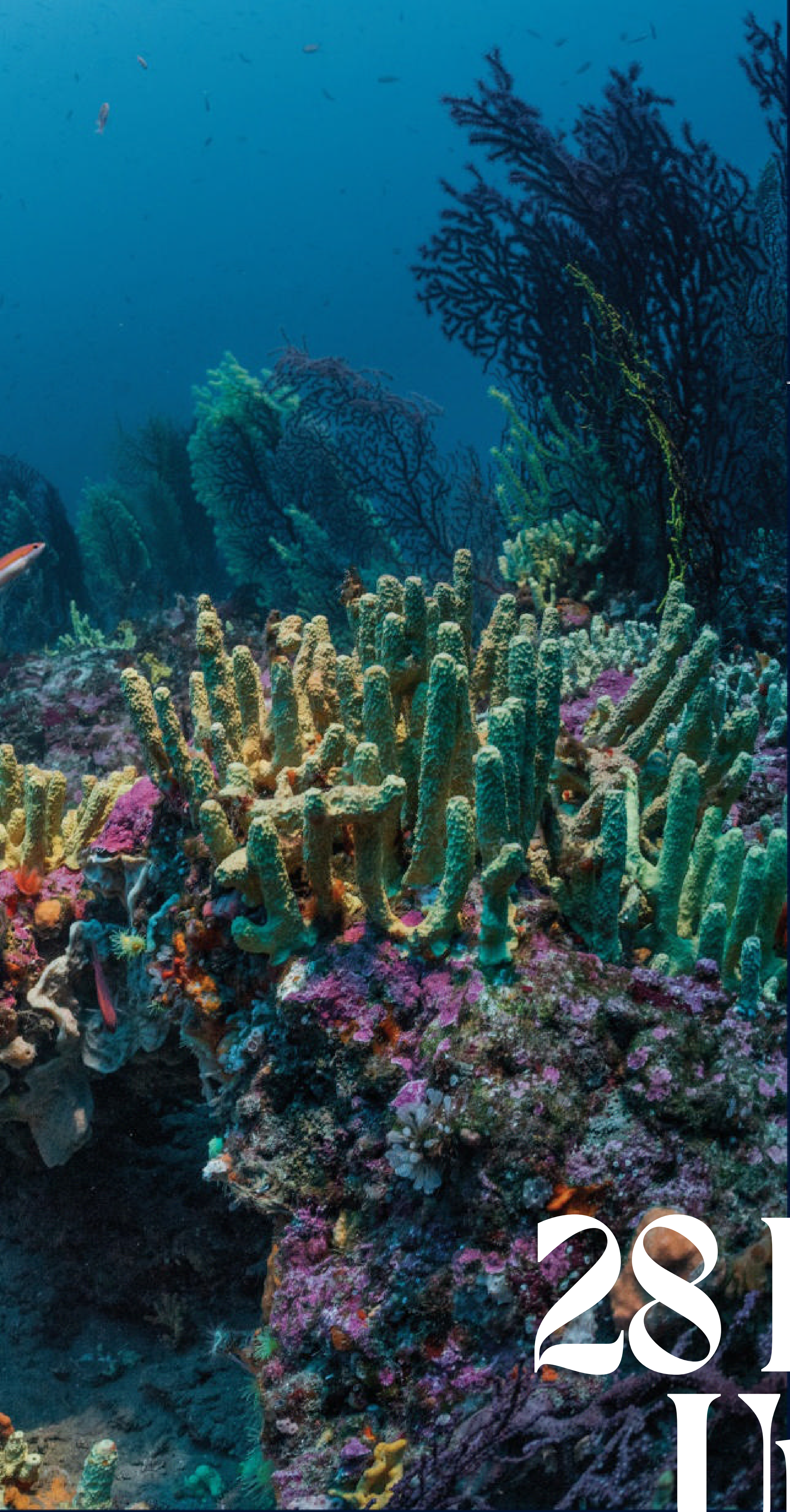
Many organizations are working to save or restore coral reefs, including those mentioned in this story as well as the National Geographic Society's Pristine Seas project. Check their websites to see how to donate or to find volunteer opportunities either on land or at sea.

For more stories about how to help the planet, go to *natgeo.com/planet.*

LAURENT BALLESTA AND THREE OTHER EXPLORERS SPENT A MONTH IN A TINY CAPSULE AND DIVED ON THE FLOOR OF THE MEDITERRANEAN. THEY FOUND AMAZING SEA LIFE—AND SIGNS OF OUR IMPACT ON A MYSTERIOUS LANDSCAPE.

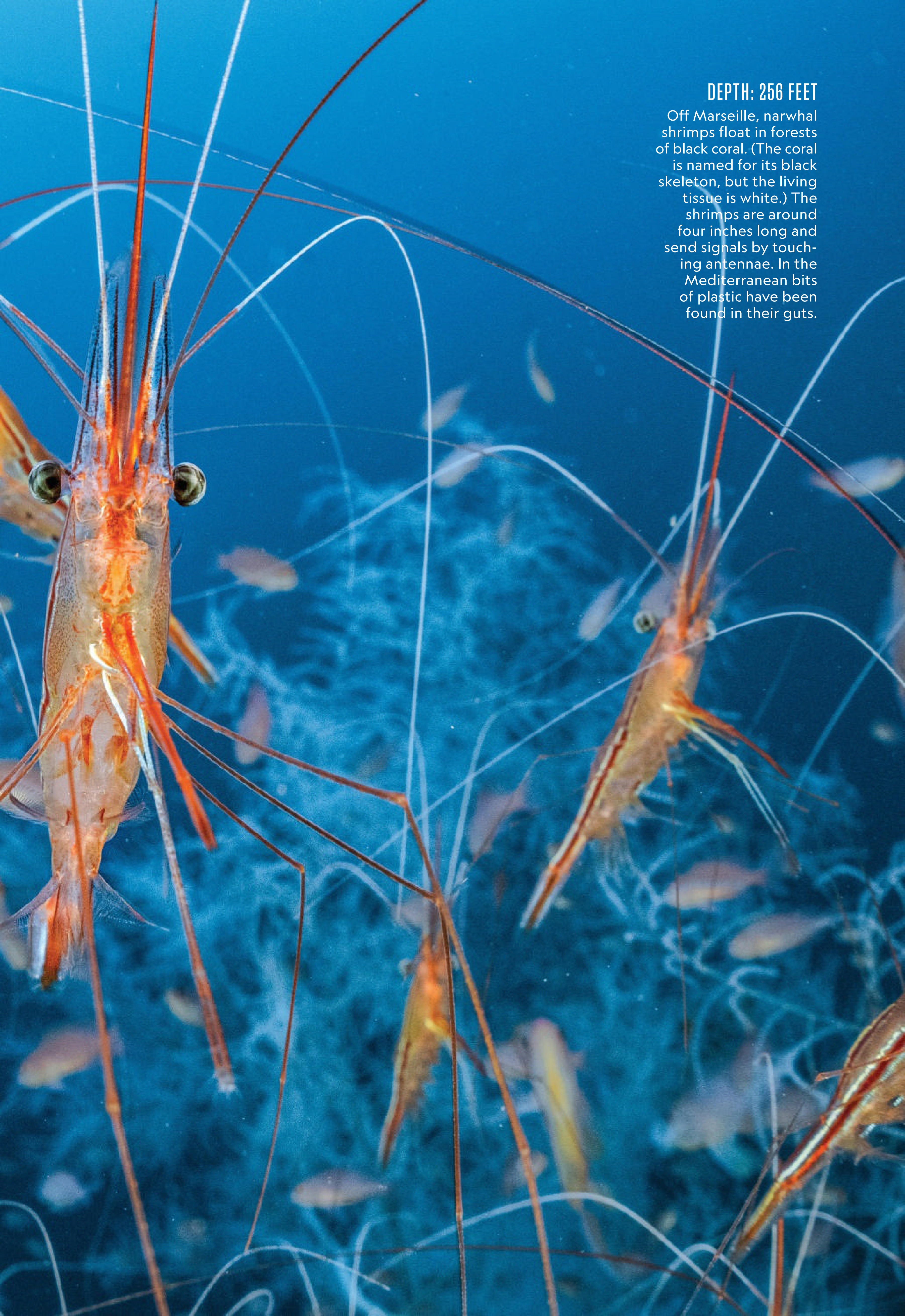
STORY AND PHOTOGRAPHS BY

LAURENT BALLESTA



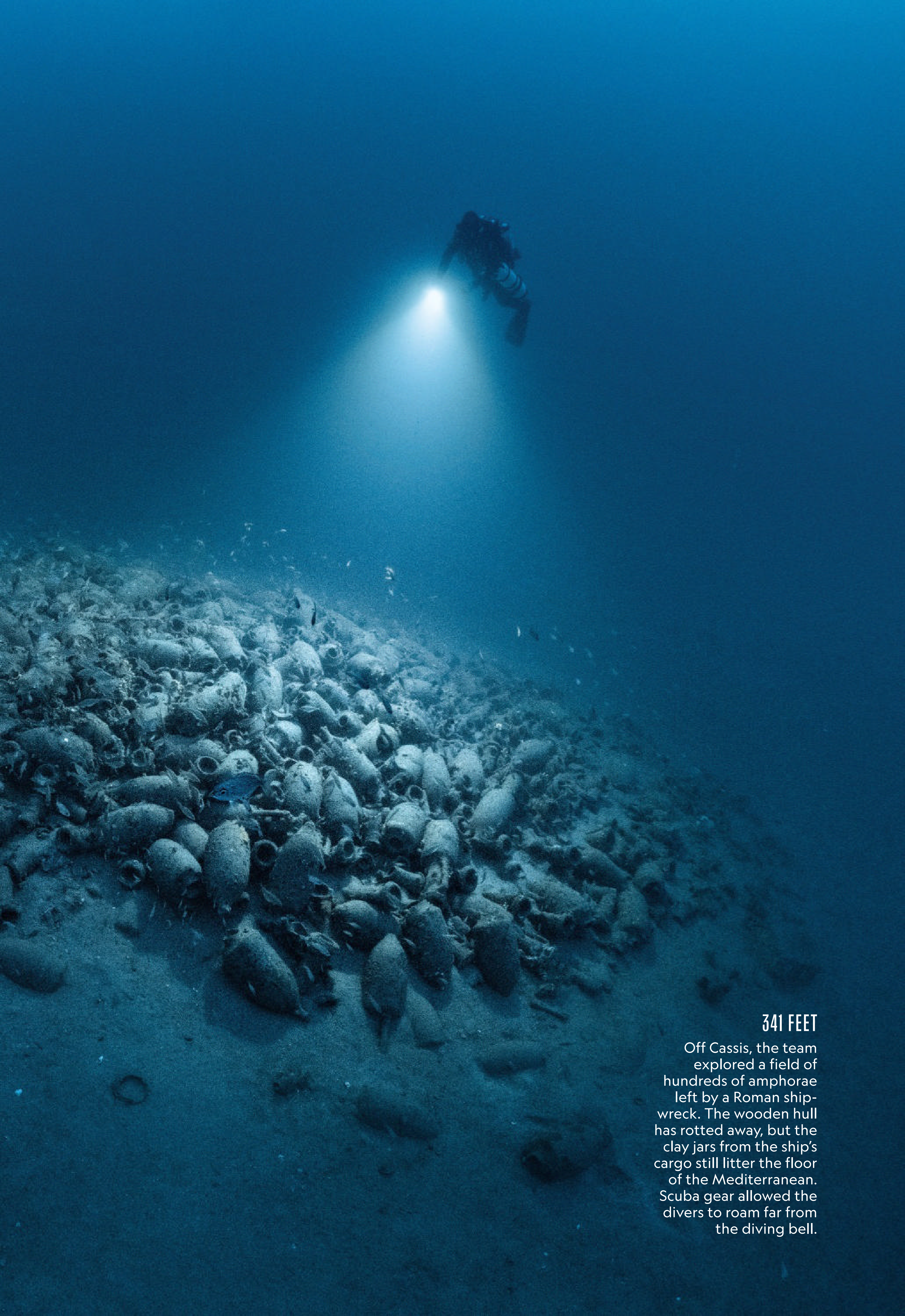
A diving bell carried the author's team to the seafloor every day from their pressurized capsule on a floating barge. Off Cassis, France, 223 feet down, a forkbeard noses around a reef built by coralline algae.

28 Days Under the Sea



DEPTH: 256 FEET

Off Marseille, narwhal shrimps float in forests of black coral. (The coral is named for its black skeleton, but the living tissue is white.) The shrimps are around four inches long and send signals by touching antennae. In the Mediterranean bits of plastic have been found in their guts.



341 FEET

Off Cassis, the team explored a field of hundreds of amphorae left by a Roman shipwreck. The wooden hull has rotted away, but the clay jars from the ship's cargo still litter the floor of the Mediterranean. Scuba gear allowed the divers to roam far from the diving bell.

TYBO

0 FEET
On the barge, Laurent Ballesta (foreground) and his mates shared 55 square feet of confinement. The hatch led to the diving bell—and to freedom in the deep.

I

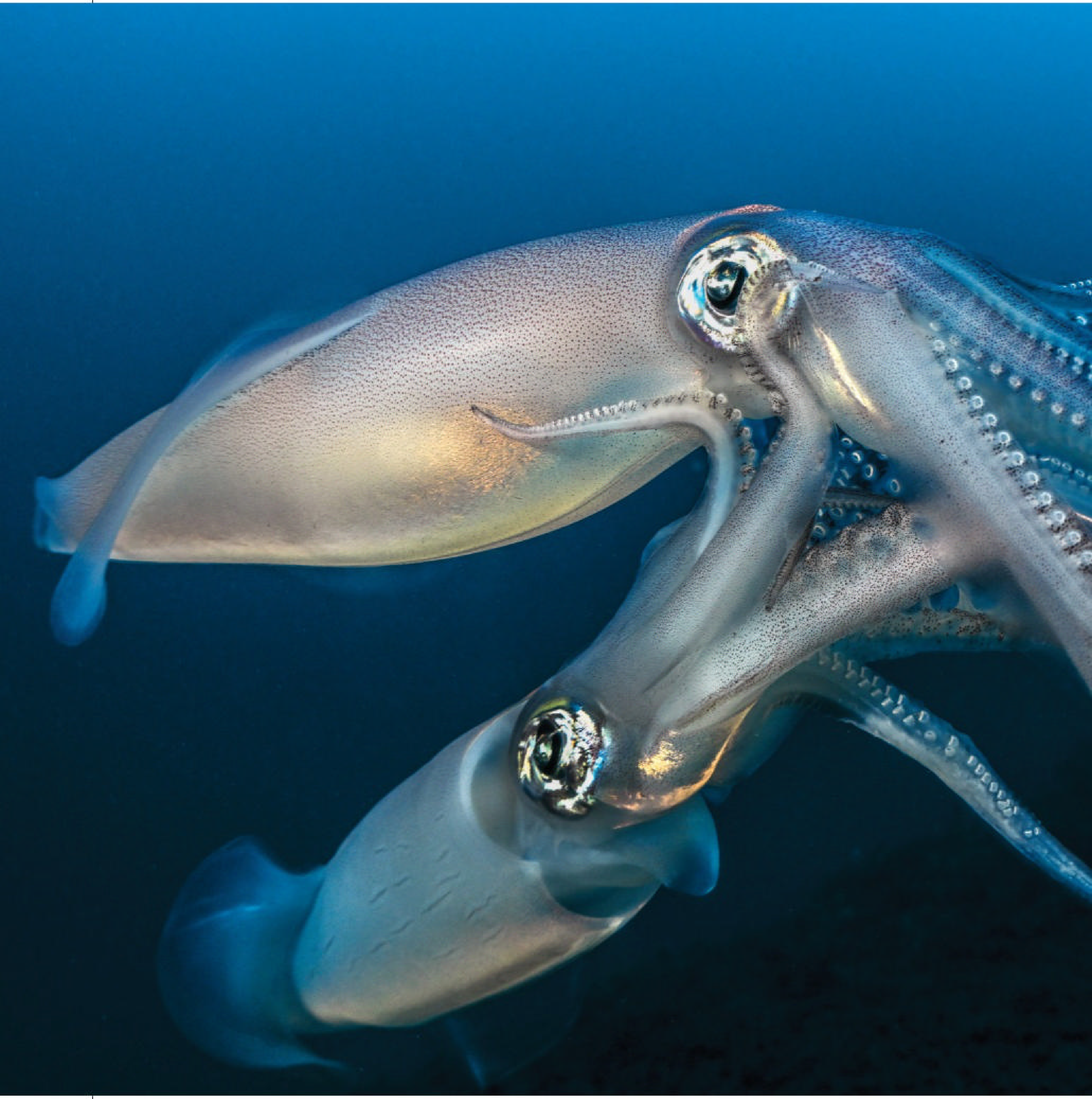
I GREW UP along the Mediterranean coast, in the south of France. My first swimming, snorkeling, and scuba diving took place on the Riviera. As time passed, and the Mediterranean became my professional home base, I watched this torrentially visited coast be ravaged by unbridled development—and I also saw, at depths of more than 150 feet or so, worlds that still seemed intact. Until recently, however, I'd gotten only brief glimpses of them. When you're scuba diving, it takes four to six hours just to ascend from such depths; you have to decompress slowly to avoid dying from the bends. So time on the bottom is frustratingly short, usually only five or 10 minutes.

In July 2019 we changed that. For 28 straight days my four-man team lived in a cramped, pressurized habitat on a barge in the Mediterranean, breathing a high-pressure mix of helium and oxygen, descending to the seafloor each day in a diving bell. We worked like saturation divers in the offshore oil industry—but unlike such divers, who typically are tethered to a bell by an umbilical, we put on scuba gear, with rebreathers that

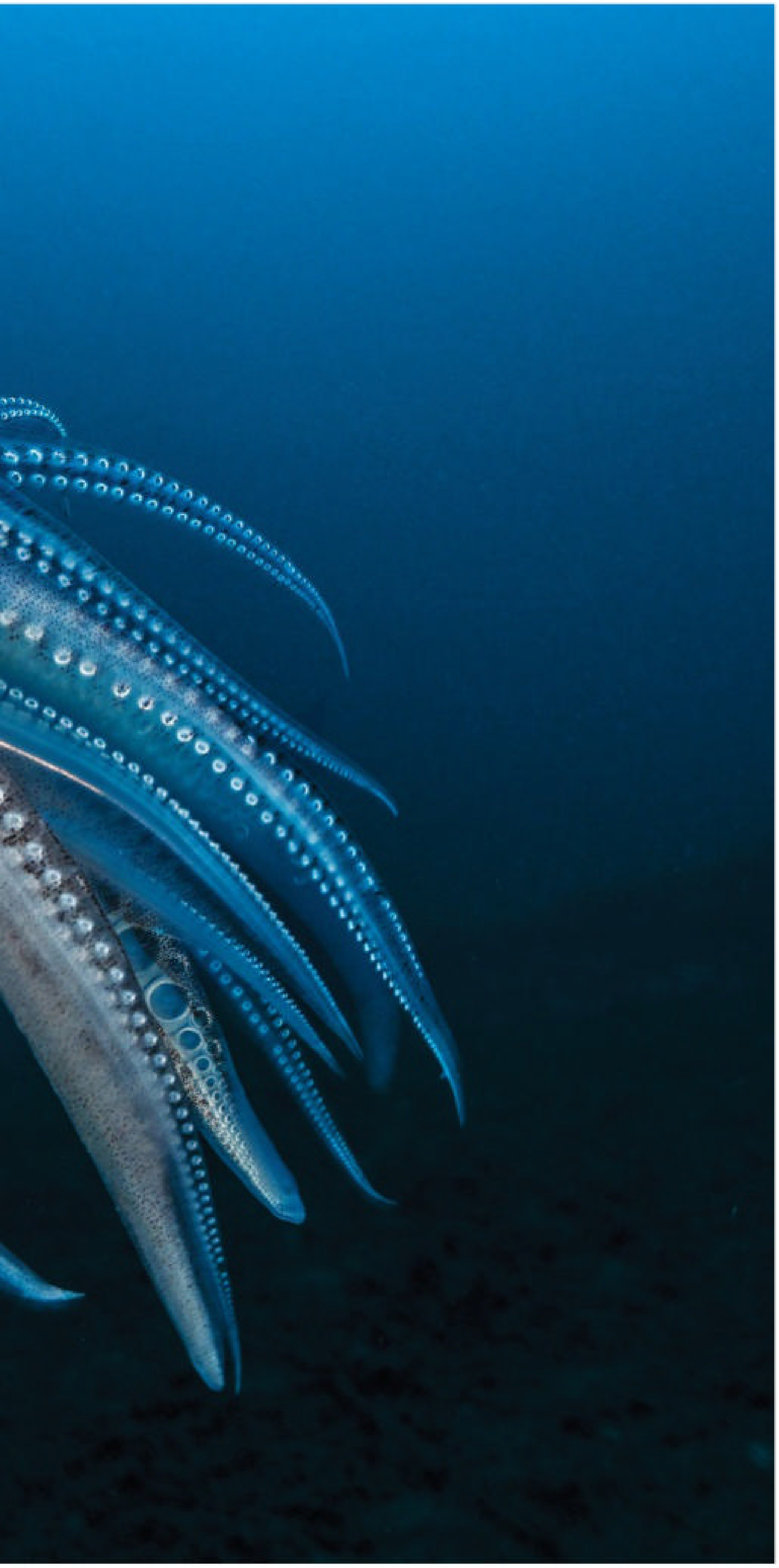
10 FEET

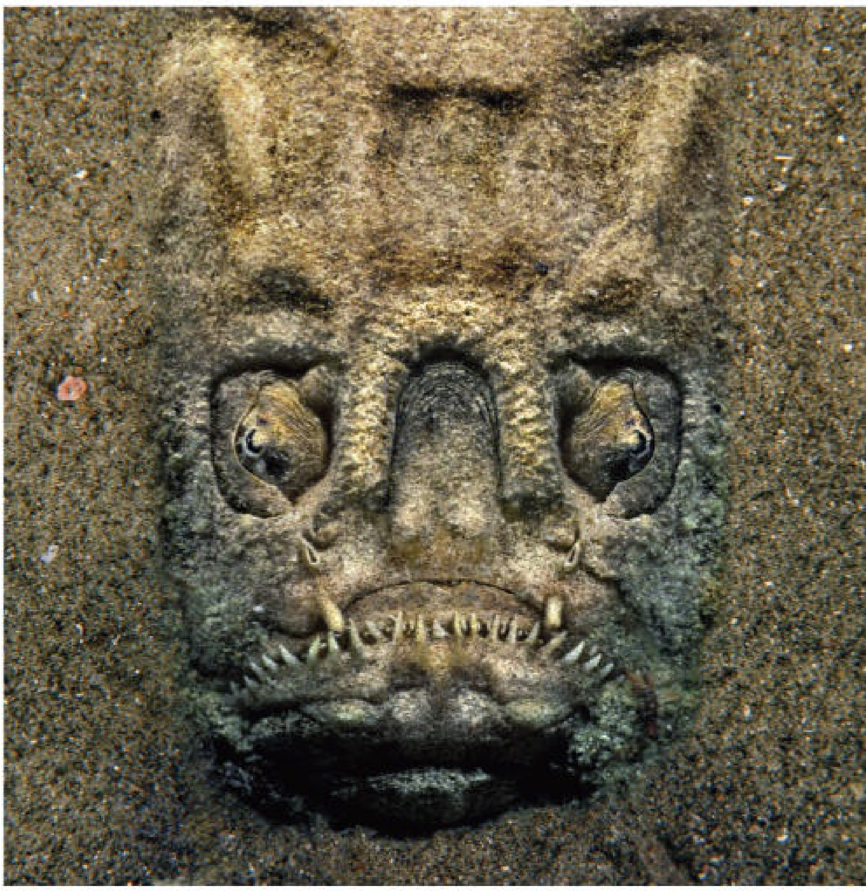
Support crew member Cedric Gentil floats upside down on the flat bottom of the barge, next to the diving bell shaft. By keeping the pressure inside the habitat and the bell the same as the seafloor, the team avoided the need for time-consuming decompressions between dives.

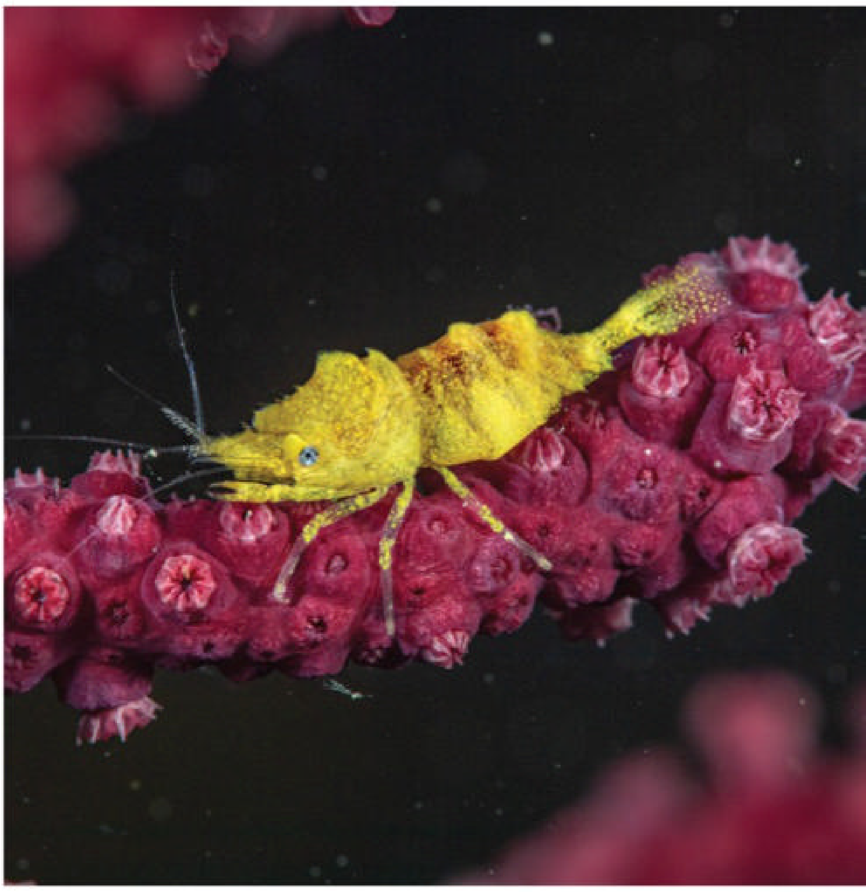
JORDI CHIAS



Humans have crisscrossed the Mediterranean for millennia, but the bottom is a world even less known than our moon.







223 FEET

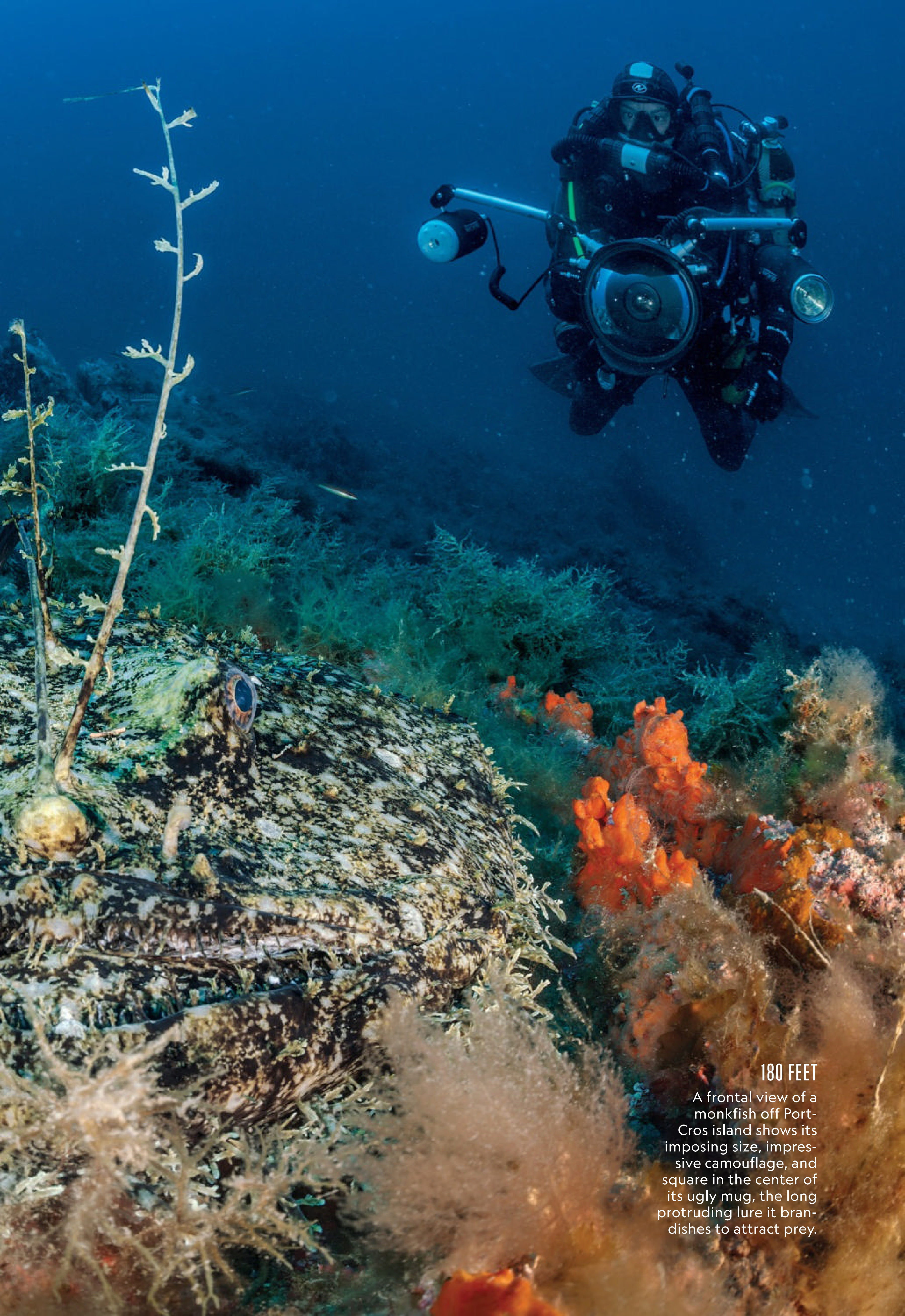
On the very first dive, off Marseille, Ballesta witnessed a rare sight: Two veined squid engaged in a delicate mating dance, their tentacles entwining. The male is on the bottom, awaiting the decisive moment.

66 FEET

Top: Not far off the Promenade des Anglais, the famous seafront in Nice, a stargazer lies buried in the mud, waiting to lunge at prey. The fish, usually less than a foot long, is common in the Mediterranean.

223 FEET

Bottom: A shrimp clinging to the branch of a purple gorgonian coral off Cassis seems poorly camouflaged—perhaps it's out of place: This species, *Balssia gasti,* has been seen in various colors, usually matching its coral host. It's less than an inch long.



180 FEET

A frontal view of a monkfish off Port-Cros island shows its imposing size, impressive camouflage, and square in the center of its ugly mug, the long protruding lure it brandishes to attract prey.

filtered carbon dioxide from our exhalations. That meant we could explore the bottom freely—for hours, not minutes.

Because both the bell and the habitat (and the bathroom in between) were kept at the same high pressure as the seafloor—as much as 13 times surface pressure—we didn't have to decompress each time we ascended. Instead we decompressed just once at the end of the mission, for nearly five days, before opening the heavy metal hatch of our capsule and breathing the open air once again.

On July 1, 2019, off Marseille, that hatch clanged shut behind us after we entered the diving bell, all geared up in our red suits for our first elevator ride down. It felt as if we were in a vessel taking us to the moon. At the seafloor, as we exited through a bottom air lock and swam away, the feeling was incredible: We were deepwater aquanauts leaving our link to home. I took a look back at the bell, fading in the blue. On that first dive, around 226 feet down, we kept it in sight.

Humans have crisscrossed the Mediterranean for millennia, but the bottom is a world even less known than our well-mapped moon—and unlike the moon, it's full of life. We wandered slowly, without hurry, in Calanques National Park, where Jacques Cousteau and Louis Malle came in the 1950s to make *The Silent World,* a film that introduced a generation to undersea life. On that first dive we saw an animal I'd seen only once before, a decade earlier, for an instant: the veined squid. A pair of them were mating right in front of us. The male passed under the female, and their tentacles intertwined; the male slipped his lower arm, which carries the sperm, under the female's mantle. Seconds later, the female swam into a small cave and hung long clusters of fertilized eggs from the ceiling.

These squid live only three years or so and get just one chance to reproduce. Once in a lifetime—and we were there. As far as I know, the behavior had never been documented before. For our first day, it seemed a good omen.

IN THE 1960s Cousteau pioneered the use of seafloor habitats along this same coast, living on the bottom for weeks at a time. We had a great advantage: We weren't tied to one spot. In 28 days our barge, towed slowly by a tugboat, traveled more than 350 miles, from Marseille to Monaco and back. We dived in 21 places.

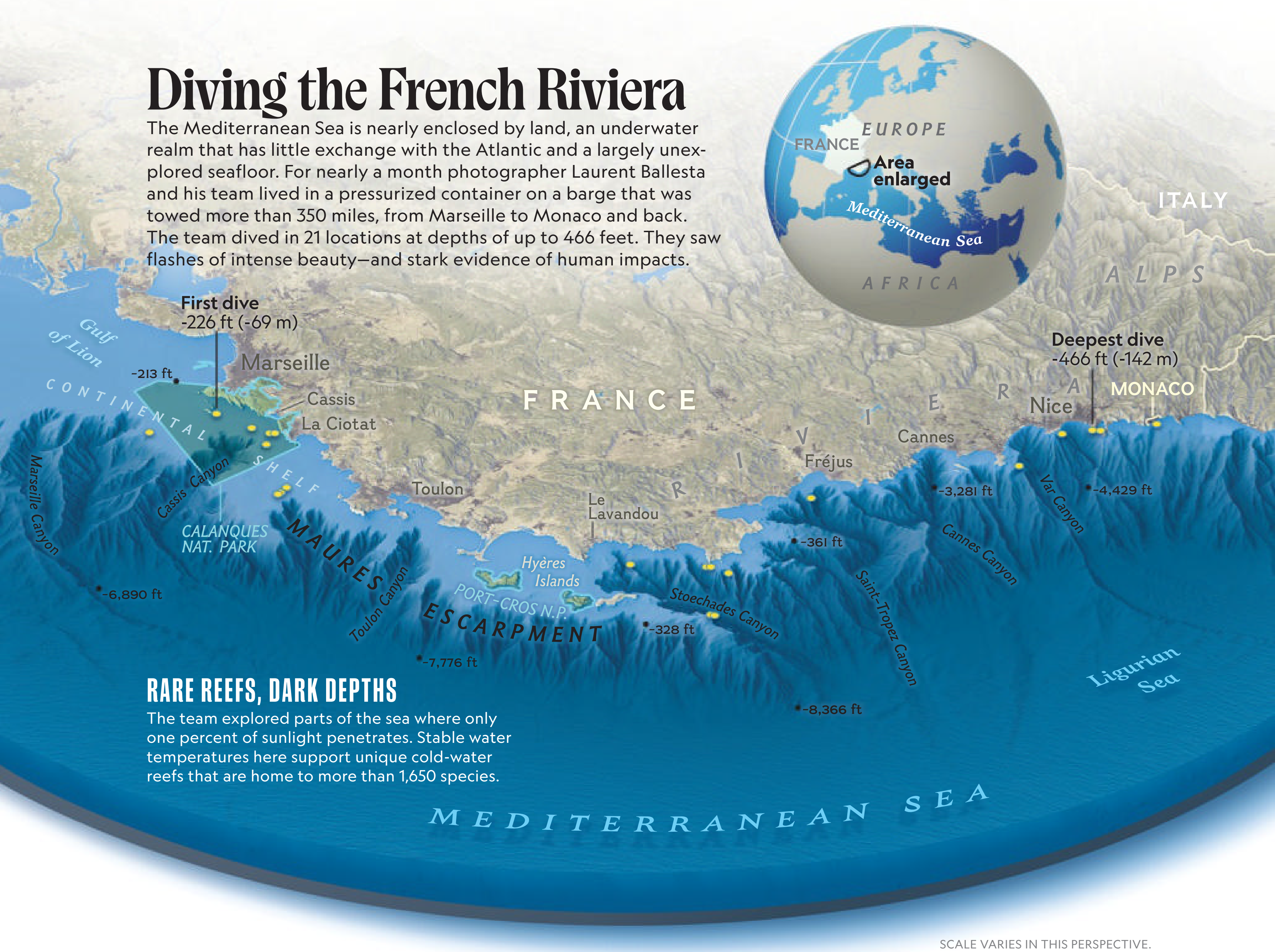
In our 55-square-foot habitat, the four of us—Yanick Gentil, Thibault Rauby, Antonin Guilbert, and I—were voluntary prisoners. There we rested, ate meals passed through a small air lock by the crew on deck, and waited for the next dive. The dives were our escape. Every day we endured violent contrasts: From the stifling heat in the cramped steel container to the bone-chilling immensity of the depths, from mind-numbing inaction to vital vigilance, from desperation and depression to ecstasy and euphoria. At the end of each day, we were exhausted. And we couldn't wait to do it all over again.

The gas mix we breathed, 97 percent helium and 3 percent oxygen, prevented nitrogen narcosis and epileptic convulsions at depth. But it turned our voices into high-pitched, almost incomprehensible quacking, forcing us to communicate through microphones and software that adjusted the sound back to (almost) normal. The helium had another curious side effect: It's such a good heat conductor that it chilled us from the inside, draining our body heat with each breath. I have dived deep under the ice in Antarctica, in water that was below freezing, but I felt much colder here in my home sea, where even at depth the temperature was a steady 57 degrees Fahrenheit.

W

WE PICKED PLACES to explore that we knew to be beautiful and flourishing. Coral reefs are rare in the Mediterranean; what it has instead, at depths between 230 and 400 feet, are "coralligenous" reefs, built by red algae. They secrete hard calcium carbonate foundations that are reinforced by some animals—worms, mollusks, corals—and gnawed at by others, such as sponges.

The constant struggle creates a textured world of nooks and crannies in which more than 1,650 species can find their niche. Sparkling pink swallowtail perch are abundant, but I'd waited years to see their far more elusive cousin: the parrot sea perch, which is slenderer, with a larger eye and a distinctive tail. Off Le Lavandou, I made



Diving the French Riviera

The Mediterranean Sea is nearly enclosed by land, an underwater realm that has little exchange with the Atlantic and a largely unexplored seafloor. For nearly a month photographer Laurent Ballesta and his team lived in a pressurized container on a barge that was towed more than 350 miles, from Marseille to Monaco and back. The team dived in 21 locations at depths of up to 466 feet. They saw flashes of intense beauty—and stark evidence of human impacts.

RARE REEFS, DARK DEPTHS

The team explored parts of the sea where only one percent of sunlight penetrates. Stable water temperatures here support unique cold-water reefs that are home to more than 1,650 species.

SCALE VARIES IN THIS PERSPECTIVE.
STRAIGHT-LINE DISTANCE FROM MARSEILLE TO MONACO IS 107 MILES (172 KM).

what might be the first photograph of this little fish alive. Things like that convinced me there was a point to all this crazy effort.

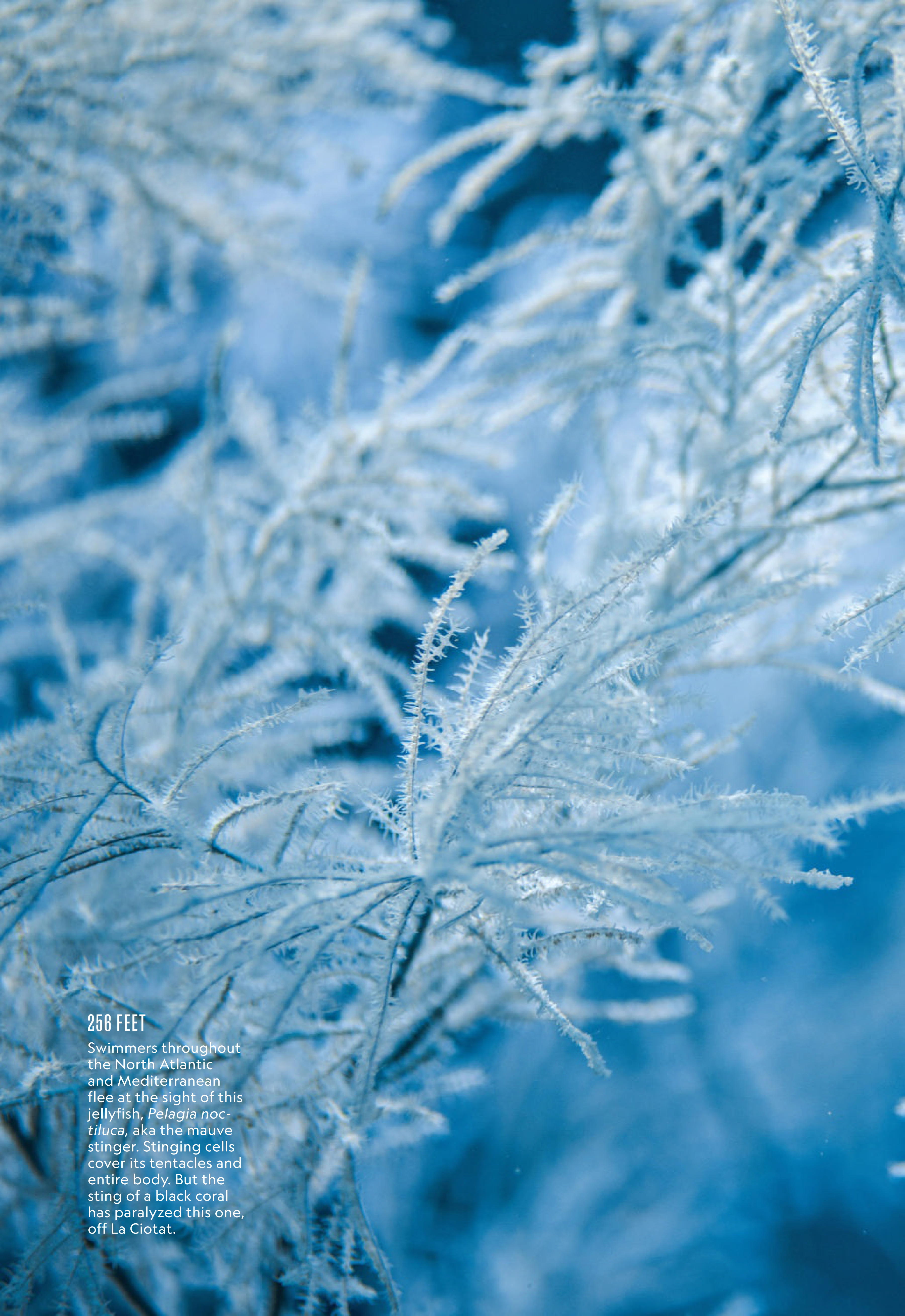
The photographs here show just a few of the creatures we met in four weeks, at depths as great as 466 feet. We saw strange shapes, bizarre attitudes, deceitful intentions. We saw a gorgonocephalid, for example, named after the Gorgons of Greek myth, who had hair of coiled serpents and the power to petrify those who looked at them. This basket star is harmless, barely four inches in diameter when coiled—but as I watched, it slowly unfurled its endlessly branching arms to 10 times that width. When these bewitching creatures meet, they often intertwine those arms in delicate caresses. Why? That remains a mystery, because like sea stars, they reproduce at a distance, without touching, discharging their gametes into the current.

At 466 feet, only one percent of the sun's light penetrates the gloom. But there are no longer any plankton either, so the water is clear, and even in the gloom it's possible to see and photograph vast spaces. Just off Villefranche-sur-Mer, where the Alps extend under the Mediterranean and the seafloor drops off steeply, I was suddenly afforded views like a mountaineer, onto another Earth, right next to our own.

Those two worlds are connected. The seafloor mud we sampled contained pesticides, hydrocarbons, carcinogenic PCBs. Surface waters were alive with noise and human activity. Fleeing such pressure, the large animals we met—monstrous monkfish, dragonlike congers, tanklike lobsters—all seemed to have retreated to greater depths. There, the Mediterranean is still alive. Its heart is still beating. But what sort of future will we offer it? ☐

Photographer and biologist **Laurent Ballesta** has dived among frenzied sharks in Polynesia, under ice in Antarctica, and with coelacanths off South Africa—and told the tales for *National Geographic*.

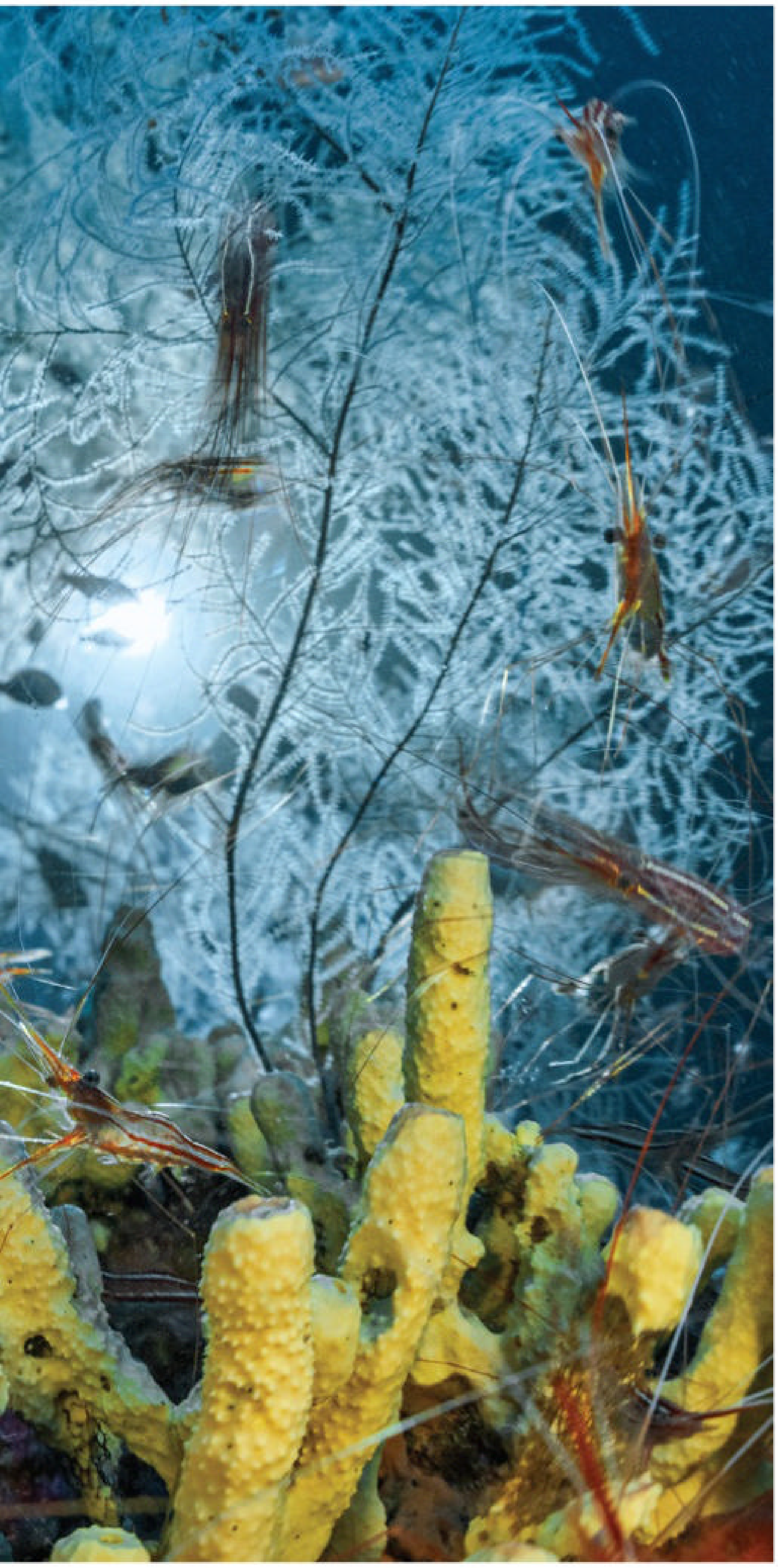
ROSEMARY WARDLEY, NGM STAFF. RELIEF: ERIC KNIGHT
SOURCES: EMODNET BATHYMETRY CONSORTIUM (2020); NASA; CORINE LAND COVER (CLC) 2018; EC JRC/GOOGLE; GREEN MARBLE; MEDTRIX PLATFORM

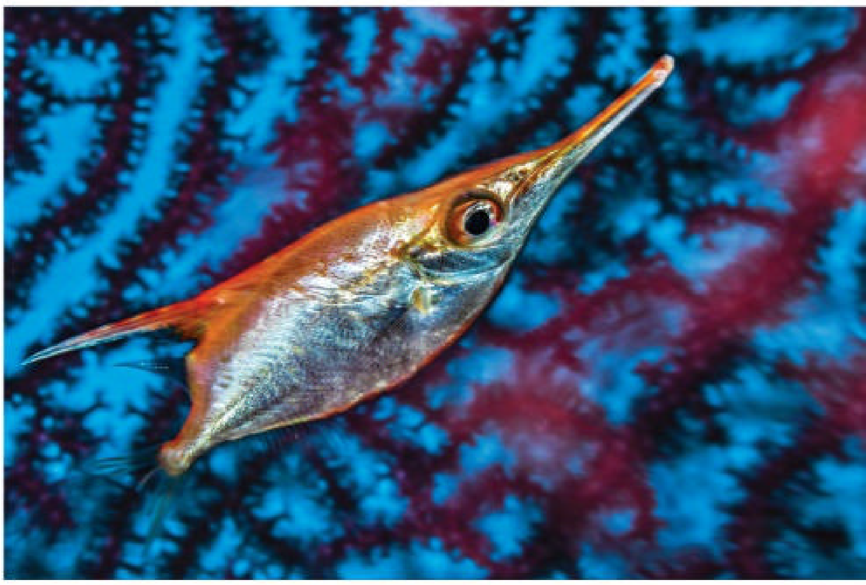


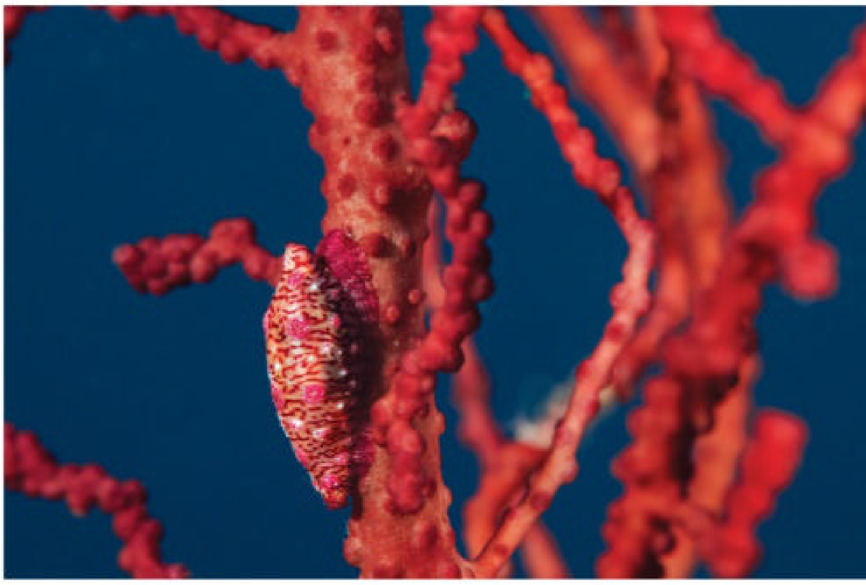
256 FEET

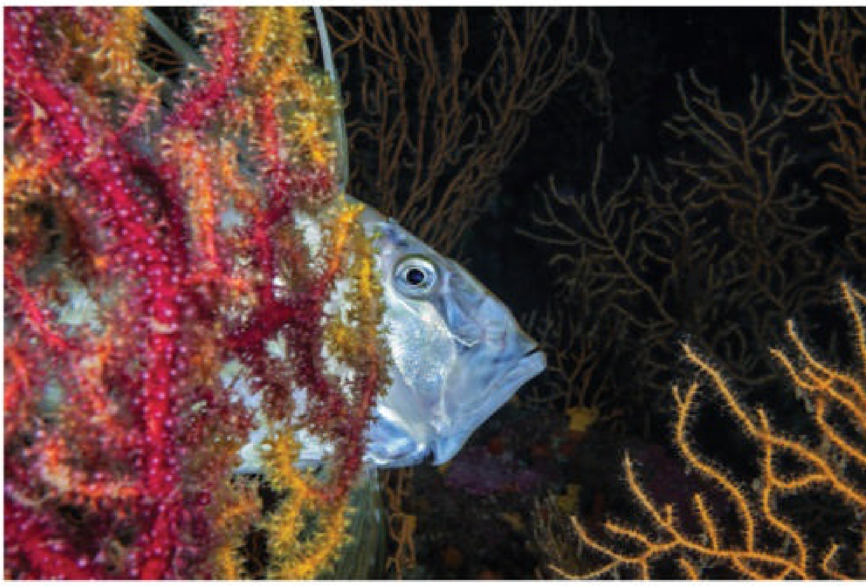
Swimmers throughout the North Atlantic and Mediterranean flee at the sight of this jellyfish, *Pelagia noctiluca,* aka the mauve stinger. Stinging cells cover its tentacles and entire body. But the sting of a black coral has paralyzed this one, off La Ciotat.

We saw creatures with strange shapes, bizarre attitudes, and deceitful intentions.









256 FEET
Scattering some as it scarfs others, a red scorpion fish feeds on narwhal shrimps on a reef off Marseille. "Coralligenous" reefs built by red algae and other species are the deep Mediterranean's biodiversity hot spots.

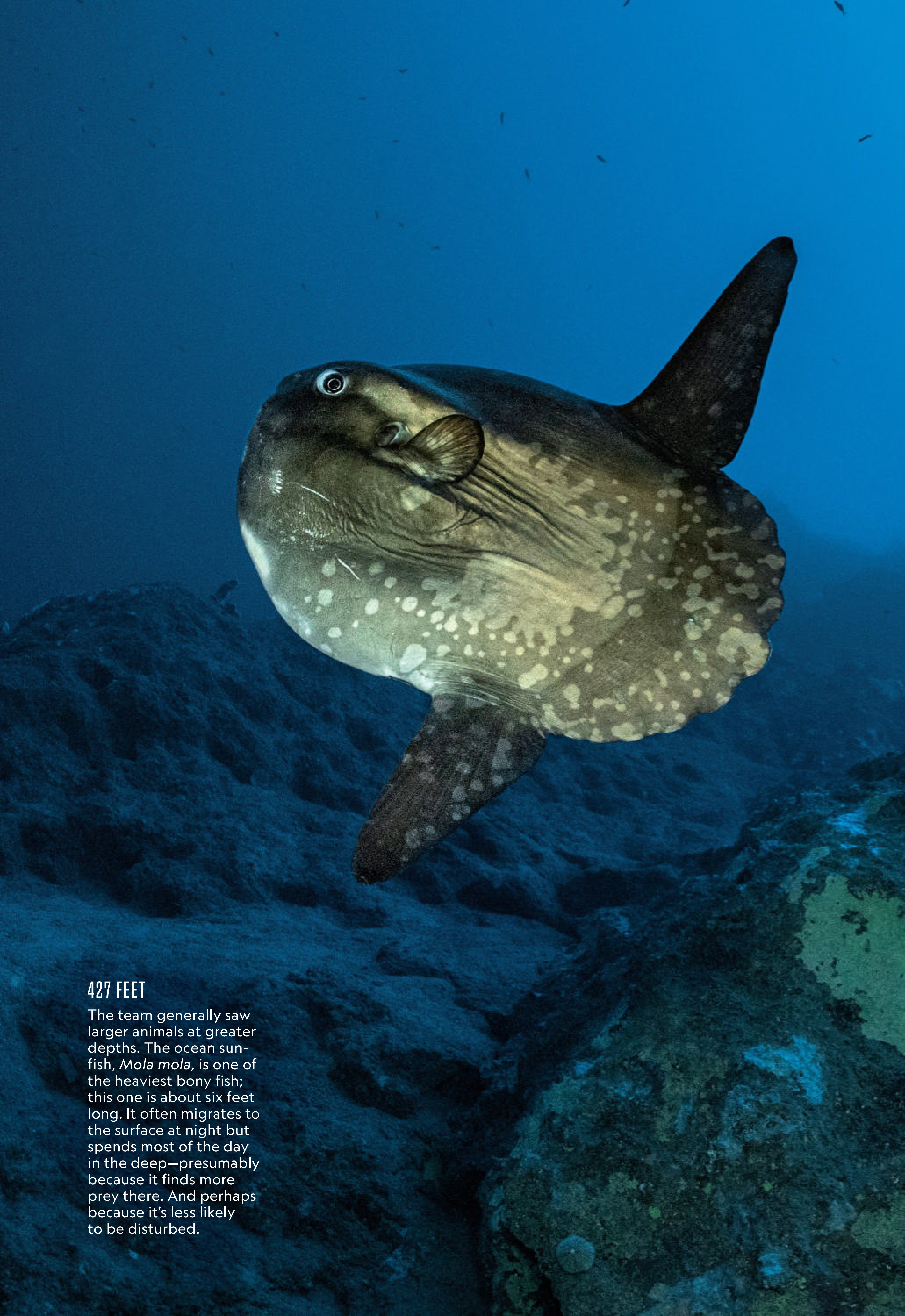
410 FEET
Top: The longspine snipefish, six inches long or so, has big eyes for seeing in the dimly lit deep and a long, toothless snout for sucking up shrimps or snails. It hangs around muddy seabed areas all over the world.

236 FEET
Middle: A purple cowrie snail hides on a gorgonian coral. Gorgonians grow in dense forests in the Mediterranean, providing habitat for other species. But warming waters and invasive algae threaten them.

223 FEET
Bottom: The John Dory, another seafloor denizen, can open its mouth wide to down small fish, cuttlefish, or shrimp. It in turn is popular at restaurants on the Riviera, many of which bear its French name—the St. Pierre.

312 FEET

“Modesty forces the familiar coastal moray to migrate towards the dimly lit depths to mate,” Ballesta writes. He photographed this pair off La Ciotat. After gaping at each other a bit, the eels entwined their slithery bodies and cast sperm and eggs into the water.



427 FEET

The team generally saw larger animals at greater depths. The ocean sunfish, *Mola mola,* is one of the heaviest bony fish; this one is about six feet long. It often migrates to the surface at night but spends most of the day in the deep—presumably because it finds more prey there. And perhaps because it's less likely to be disturbed.

ROBERT BALLARD MAY BE BEST KNOWN FOR FINDING THE *TITANIC*, BUT HIS HUNT FOR SCIENTIFIC AND CULTURAL TREASURES IS A LIFELONG EXPEDITION.

BY

RACHEL HARTIGAN

Robert Ballard emerges from the submersible *Alvin* after a 1979 dive to the Galápagos Rift. Ballard's push for direct visual observation of the deepest reaches of the ocean has led to momentous scientific and historic discoveries.

SAMUEL W. MATTHEWS

The Searcher of the Deep

When Ballard and his crew found the *Titanic* in 1985, they first located a boiler and then the rest of the ship, including its rusty bow. Few knew then that Ballard also was on a secret mission for the U.S. Navy to chart the wreckage of two nuclear submarines.

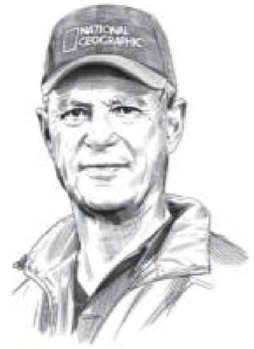
EMORY KRISTOF

I

“IF THE PLANE WAS IN THERE, it would have seen it,” says Robert Ballard, referring to the 14-foot autonomous surface vehicle (ASV) launched from his 211-foot exploration vessel, the E/V *Nautilus.*

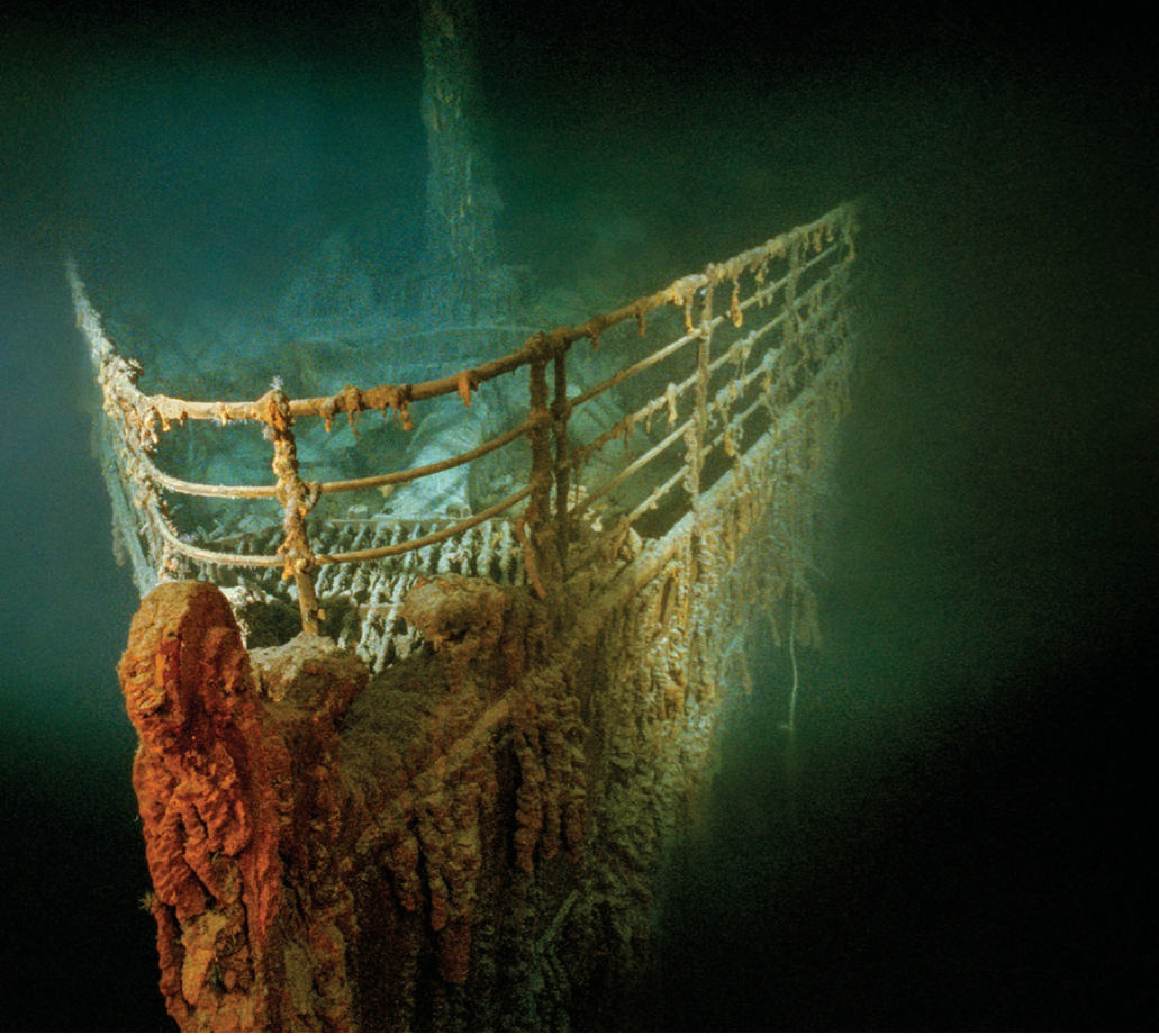
He is sitting in his cabin on the *Nautilus,* gesturing at a map of the seafloor on his computer screen. The ASV, a remote-controlled boat equipped with multibeam sonar, had generated the underwater image as it skirted the reef surrounding Nikumaroro, the remote Pacific island where Ballard was searching for Amelia Earhart’s Lockheed Electra 10E.

More than four decades after discovering hydrothermal vents and black smokers on the seafloor, three decades after finding the *Titanic,* and nearly 20 years after locating John F. Kennedy’s World War II patrol boat, the 78-year-old National Geographic explorer-at-large is still in the business of solving the ocean’s great mysteries. Earhart, who disappeared while trying to become the first person to fly around the world at the Equator, has been missing for more than eight decades. Before this expedition in 2019,



The National Geographic Society, committed to illuminating and protecting the wonder of our world, has funded Explorer-at-Large Robert Ballard’s ocean expeditions for more than 40 years.

ILLUSTRATION BY JOE MCKENDRY



Ballard had announced that if her plane was there, he would find it.

"We did the whole enchilada," he says over the thrum of the *Nautilus*'s motors as the ship navigates away from the island. He's uncharacteristically subdued after an intensive period of late-night watches and eye-straining examinations of sonar backscatter and underwater video footage. But he soon spins in his chair to explain the images on his screen. Above Ballard's desk is an illustration from Jules Verne's *20,000 Leagues Under the Sea* of a giant squid battling humans. To his left, a TV monitor linked to the remotely operated vehicles (ROVs) that he helped design serves as his porthole into the ocean's depths.

Ballard conducted the search for Earhart's plane with his usual relentlessness, focusing his attention on the northwestern edge of the 4.7-mile-long island, where a 1937 photograph showed what looked like an Electra's landing gear jutting from the reef. Drones aimed their cameras at the surf breaking over the reef, the ASV surveyed the water down to 754 feet, and the ROVs *Hercules* and *Argus* inspected the jagged slopes nearly 5,000 feet down to the ocean floor. The *Nautilus,* with its multibeam sonar, circumnavigated the island five times, the ASV did so three times, and the drones once. Ballard and his crew watched it all from the ship's monitors.

They didn't find Earhart's plane.

AN EXPLORER'S LIFE

Drawn from hours of never-before-seen footage, *Bob Ballard: An Explorer's Life* will air June 14 at 10/9c on National Geographic.

"We gave it a hell of a shot," says Ballard, pointing out that his discovery of the *Titanic* in 1985 was the third attempt by searchers to locate the ocean liner, and that it took him two expeditions to find the *Bismarck,* the Nazis' largest battleship, in 1989. "Sometimes I get it right off the top," he says. "Sometimes it takes ..."

He shifts gears. "I learned a lot," he continues. "I was eliminating possibilities. It was fun."

Ballard doesn't let setbacks—or anything else really—slow him down. But after 157 expeditions, the man who introduced the public to deepwater exploration is taking stock. This spring he's publishing a memoir and releasing a documentary, both with National Geographic. His team at the Ocean Exploration Trust has funding through the next decade, whether he's at the helm or not.

"I've started divesting my world," he says. "I'm letting my brain loose, which is scary."

WHEN BALLARD WAS 12, he saw the movie *20,000 Leagues Under the Sea,* in which the mysterious Captain Nemo roves the waves in an opulent submarine called the *Nautilus.* "It just captivated me," he says. Although Ballard spent his childhood in Southern California beachcombing, fishing, and bodysurfing, it had never occurred to him that there was an entire world under the ocean's surface. He told his parents that when he grew up he wanted to be Captain Nemo.

But the path from dream to reality wasn't smooth. The middle child of an aviation engineer and a brilliant housewife, Ballard struggled in school. He found reading and writing difficult; homework took him twice as long as it did his older brother, Richard, who sailed through school and eventually earned a doctorate in physics. (His sister, Nancy Ann, had a genetic mutation that required her to be cared for all her life.)

Once Ballard locked on to becoming an oceanographer, a real-life Captain Nemo, he had a purpose. "I just knew that the only way I could overcome things was to be dogged," he says. He did well at the University of California, Santa Barbara, but not well enough to get into graduate school at the Scripps Institution of Oceanography, which he'd been gunning for since he was a kid.

Salvation came in the form of the Army Reserve Officers' Training Corps, which he'd joined as an undergraduate. When it was time for active service, he requested a transfer to the Navy. He received it, along with orders to move to Massachusetts to serve as a liaison with research organizations such as the Woods Hole Oceanographic Institution. "Somehow," he writes in his memoir, "I'd ended up in the perfect place."

"THE SUB IS NOW falling peacefully toward the rift floor 9,000 feet below us," Ballard wrote in his first article for *National Geographic,* which ran in the May 1975 issue. Ballard was describing his descent in *Alvin,* the cramped submersible operated by Woods Hole, during Project FAMOUS. This French-American expedition was the first to explore the Mid-Atlantic Ridge, the longest mountain range on the planet. One of 10 scientists involved in the venture, Ballard witnessed with his own eyes the evidence for plate tectonics, which was then a controversial theory.

Ballard has always preferred seeing—"direct visual observation," as he puts it—to theorizing, and *Alvin* was the perfect tool for the science he wanted to do. The only submersible operated by a U.S. oceanic institution, *Alvin* could go as

Decades of discovery

During a career of exploration that has spanned nearly 60 years, Robert Ballard has completed 157 expeditions (selected ones are shown at right). He helped confirm the theory of plate tectonics, and he found the *Titanic*. More recently Ballard searched for aviator Amelia Earhart's plane, and he's been scouting U.S. waters in his continuing quest to bring the ocean's hidden mysteries to light.

CHRISTINE FELLENZ AND TAYLOR MAGGIACOMO, NGM STAFF. RELIEF: ERIC KNIGHT
SOURCES: FLANDERS MARINE INSTITUTE; GEBCO; GREEN MARBLE; OCEAN EXPLORATION TRUST; ODYSSEY ENTERPRISES

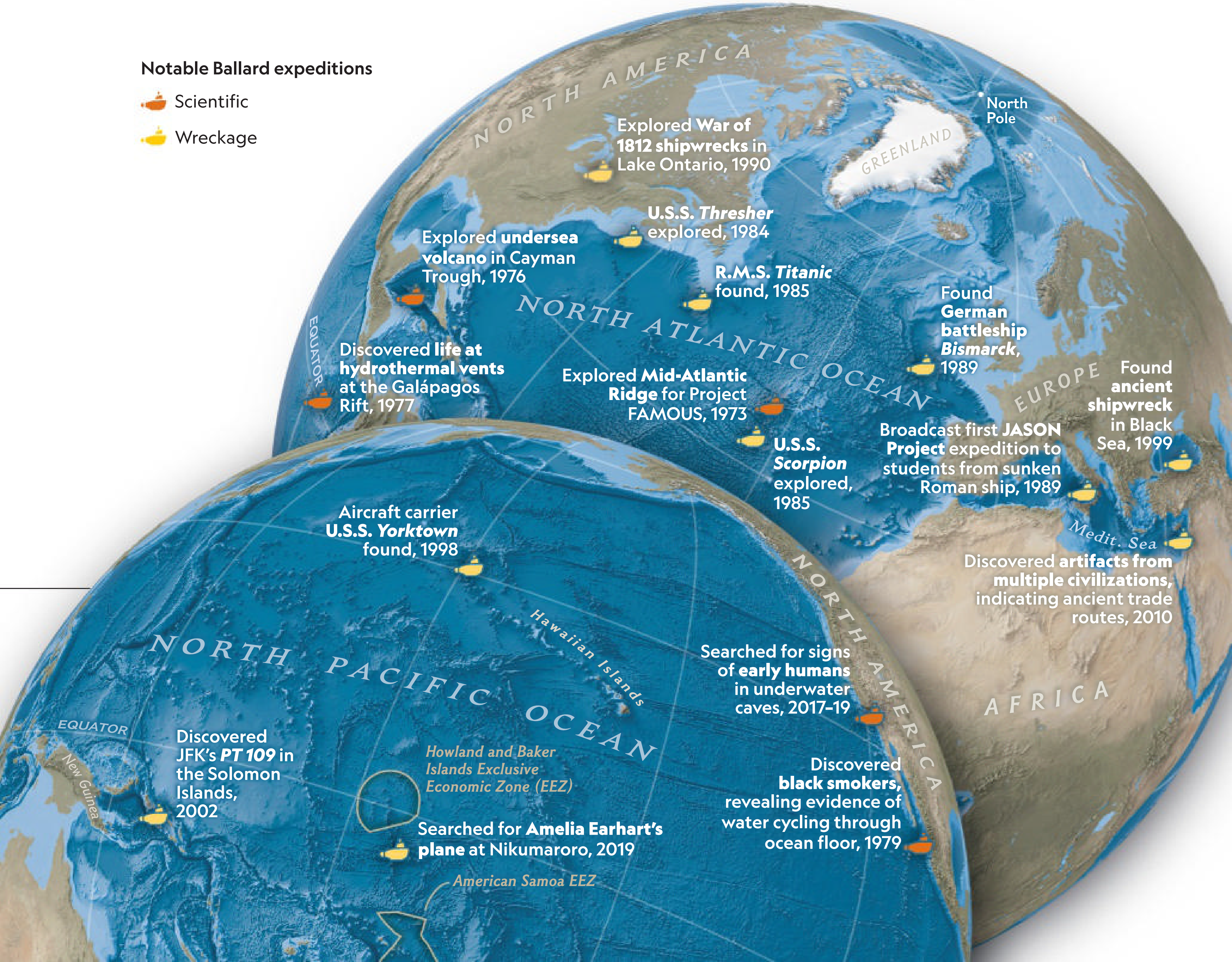
deep as 12,000 feet. If Ballard wanted to explore deep water, he needed to stick with Woods Hole and its “little white sub.” After he left the Navy, he got a Ph.D. at the University of Rhode Island and joined Woods Hole as a research scientist.

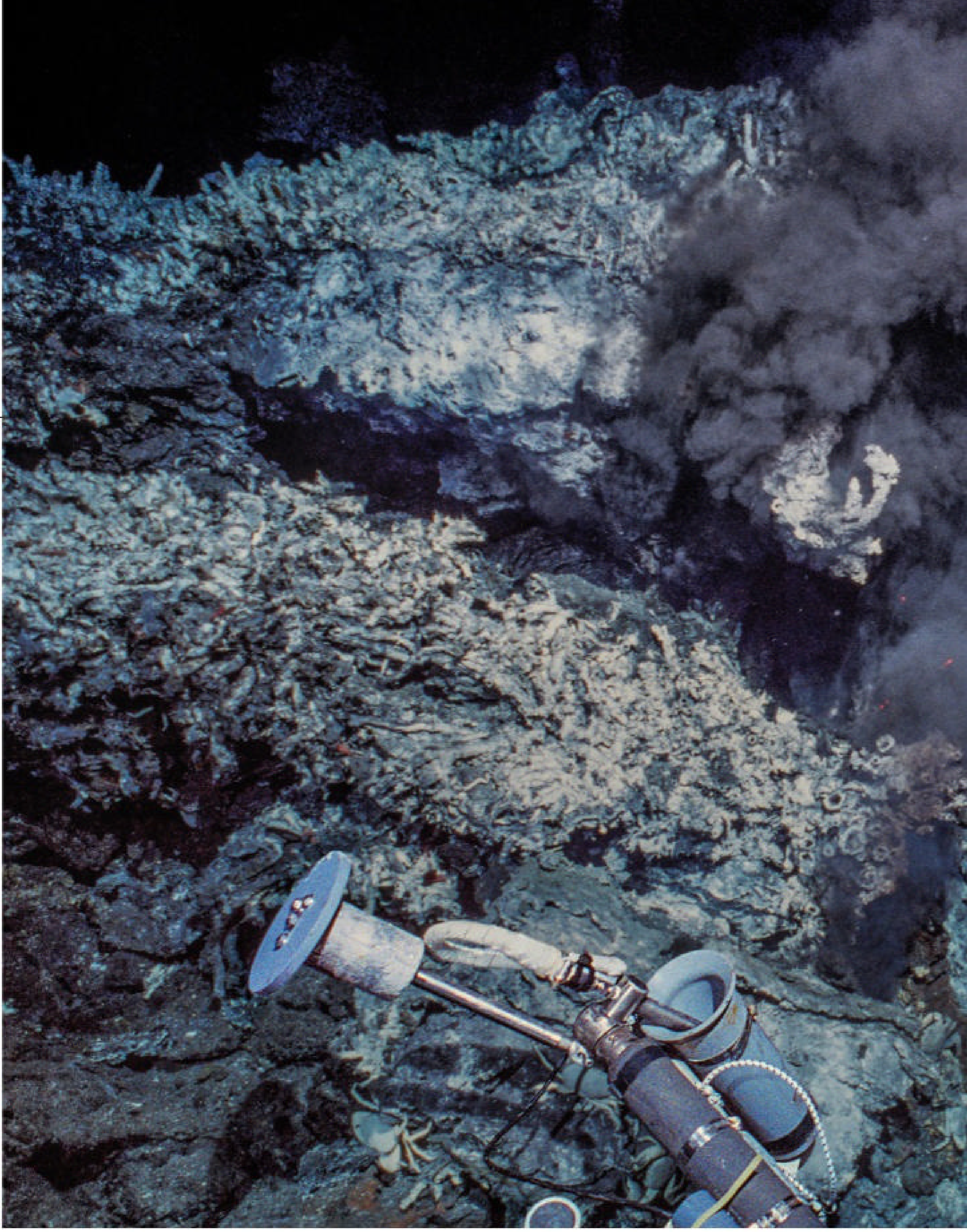
Ballard’s visual approach to science would open up new worlds. In 1977 he joined an expedition north of the Galápagos, where previously collected samples indicated puzzling amounts of hot water. He brought *Alvin* and a new tool called *Angus,* a tethered sled lugging three cameras that could go as deep as 20,000 feet. The team discovered hydrothermal vents, cracks in the ocean floor that released scalding water.

They also came across life where they least expected to find it, nearly 9,000 feet deep and in total darkness. Enormous clams. Massive mussels. Giant tube worms—all flourishing near vents in the Earth spewing hydrogen sulfide. The creatures lived off the malodorous gas through a previously unknown process called chemosynthesis, which Ballard and his team didn’t realize existed until they saw the evidence firsthand.

Ballard set about trying to figure out how to predict where hydrothermal vents might appear. In the process he discovered another unknown phenomenon. On an expedition off Baja California, his team encountered what appeared to be underwater chimneys billowing black smoke. The water near these structures was so hot it melted the tip of *Alvin*’s thermometer. The chimneys were constructed of polymetallic sulfides—the minerals had precipitated when they hit the cold seawater—and their composition revealed that enormous amounts of water cycled through the ocean floor.

Ballard’s discoveries were groundbreaking, but crewed submersibles had definite disadvantages. For one, the long commute time to the ocean bottom and back didn’t leave much time for exploring. More crucially, they could be dangerous. During Project FAMOUS, a fire broke out on a French submersible, with Ballard aboard, and *Alvin* got stuck in a fissure. On a mission to the Cayman Trough, he was in a Navy bathyscaph that hit a rock wall, rupturing a gas


Notable Ballard expeditions
Scientific
Wreckage
NORTH AMERICA
Explored War of 1812 shipwrecks in Lake Ontario, 1990
GREENLAND
North Pole
U.S.S. *Thresher* explored, 1984
Explored undersea volcano in Cayman Trough, 1976
R.M.S. *Titanic* found, 1985
Found German battleship *Bismarck*, 1989
NORTH ATLANTIC OCEAN
EQUATOR
Discovered life at hydrothermal vents at the Galápagos Rift, 1977
Explored Mid-Atlantic Ridge for Project FAMOUS, 1973
EUROPE
Found ancient shipwreck in Black Sea, 1999
U.S.S. *Scorpion* explored, 1985
Broadcast first JASON Project expedition to students from sunken Roman ship, 1989
Medit. Sea
Discovered artifacts from multiple civilizations, indicating ancient trade routes, 2010
Aircraft carrier U.S.S. *Yorktown* found, 1998
NORTH AMERICA
Hawaiian Islands
NORTH PACIFIC OCEAN
Searched for signs of early humans in underwater caves, 2017–19
AFRICA
EQUATOR
New Guinea
Discovered JFK’s *PT 109* in the Solomon Islands, 2002
Howland and Baker Islands Exclusive Economic Zone (EEZ)
Discovered black smokers, revealing evidence of water cycling through ocean floor, 1979
Searched for Amelia Earhart’s plane at Nikumaroro, 2019
American Samoa EEZ



Alvin's claw arm extends to collect sediment surrounding a black smoker—a hydrothermal vent spewing scalding, mineral-heavy water from a gash in the ocean floor. The 1977 discovery by Ballard and colleagues of hydrothermal vents—and the astonishing deepwater life-forms flourishing around them—revolutionized oceanography.

AL GIDDINGS

tank. It took six hours for the vessel to return to the surface; the crew weren't sure they'd make it until they saw the sky. Ballard began to wonder if camera-wielding robots would be better for this job.

IN 1977 BALLARD decided to take on the *Titanic,* but his first attempt was nearly catastrophic. Instead of submersibles, he was using pipes—3,000 feet of them lowered to the ocean floor from a derrick on a ship called the *Seaprobe.* A pod containing 600,000 dollars' worth of borrowed sonar and camera equipment dangled from the bottommost pipe. But before Ballard could even begin looking for the luxury liner, the entire structure collapsed in the middle of the night—derrick, pipes, borrowed equipment—most of it ending up on the bottom of the Atlantic.

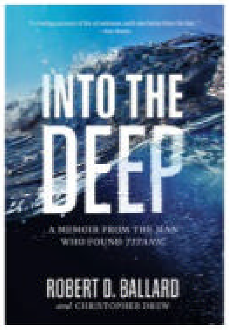
He wasn't daunted. Finding the *Titanic* was the Everest of ocean exploration, "the number one quest on everyone's list," he writes. He was too competitive and too ambitious to give up.

Again, the military opened the door. The Navy would fund Ballard's development of ROVs if it could have access to them and to Ballard's expertise for certain secret missions.

The first ROV developed was *Argo,* which transmitted live video, allowing scientists to make immediate decisions about where to explore. To the Navy, it seemed like an excellent tool for examining the wreckage of two nuclear submarines—the *Thresher* and the *Scorpion*—in the North Atlantic. To Ballard, those missions, which were kept secret until the late 1990s,

INTO THE DEEP

In his new memoir published by National Geographic, Robert Ballard shares the inside story of his many discoveries, as well as the personal challenges he has faced along the way: family tragedies, academic skepticism, and his dyslexia, discovered late in life—a gift, he now believes.



would serve as a perfect jumping-off point for the *Titanic*. The admirals agreed to give him two weeks to search, as long as he first recorded the condition of the *Scorpion* to their satisfaction.

Ballard's work on the submarines proved crucial to his discovery of the *Titanic*. The *Thresher* expedition in 1984 and the *Scorpion* in 1985 taught him how wreckage scattered underwater. Heavier objects fall directly to the ocean floor, while currents carry lighter items farther away, creating a debris field shaped like a comet.

Because time was tight and a team funded by a Texas oilman was hot on the *Titanic*'s trail, Ballard partnered with a French group, which scanned the search area with a sophisticated sonar system. Ballard assumed the French would find the ship first, and he would come afterward to provide visuals. But the French didn't find it.

Ballard set up a search grid for *Argo* based on his estimate of the size of the *Titanic*'s debris field. Then his team began what he calls "mowing the lawn," traversing the grid back and forth, back and forth. It's tedious work—until you find something. At about 1 a.m. on September 1, 1985, they did—a boiler nestled amid debris.

Public response to the discovery was immediate and overwhelming. Ballard had become, to his joy and chagrin, "the man who found the *Titanic*," a moniker that would eclipse even the most significant of his scientific discoveries.

Even so, the publicity fanned a flame in Ballard that had first been sparked by an encounter with National Geographic Society President Melville Grosvenor at a Boston diving club in 1972. Grosvenor suggested that he write for the magazine. Ballard had taken scientists down to see the wonders of the deep ocean; he thought the public should be able to witness them too.

Ballard had begun inviting reporters and photographers on his expeditions early in his career, and he'd participated in several National Geographic television specials about his work—drawing some scorn from academic colleagues. The barbs stung, but Ballard stuck to this outreach. Now he wanted to reach children, thousands of whom had sent him letters after he discovered the *Titanic*. Perhaps he could guide their fascination toward science and exploration. Plus, he says, "if you can't tell a five-year-old what you're doing, you don't know what you're doing."

This mission became more vital to him after tragedy struck.

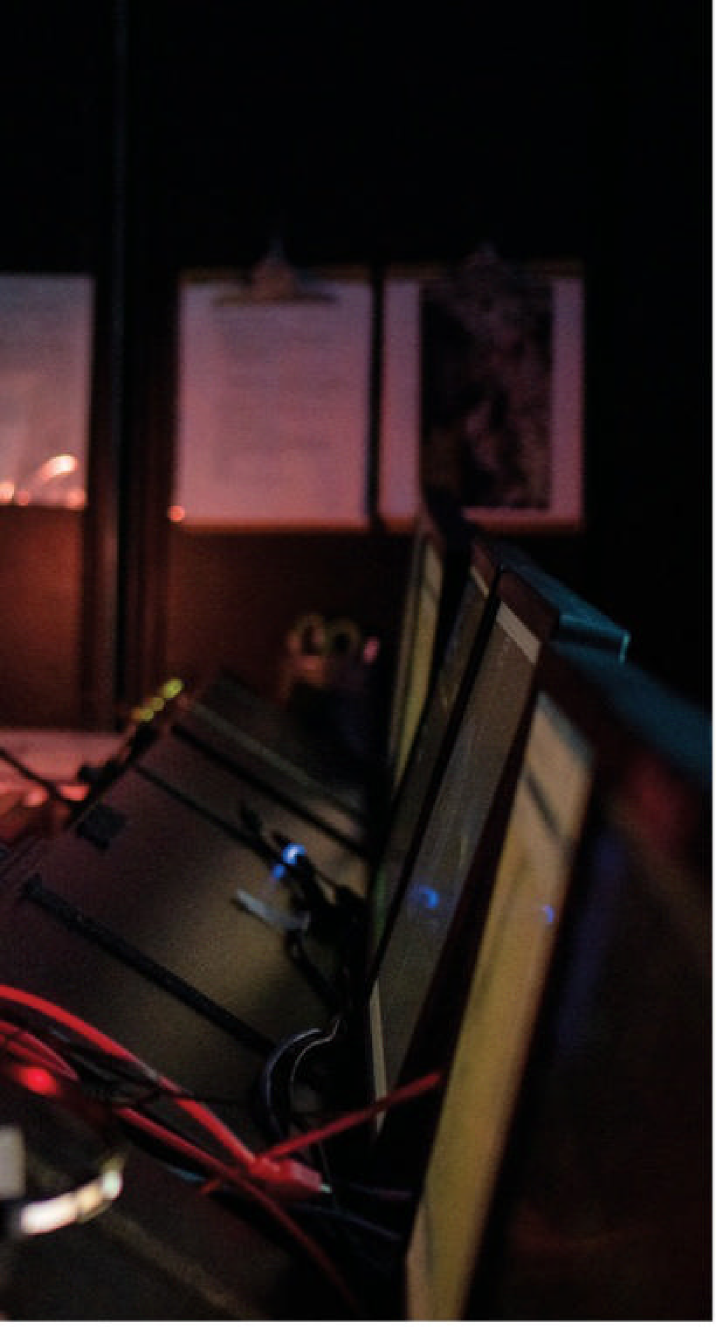
Ballard had married Marjorie Hargas in 1966, and they'd had two sons, Todd and Douglas. The marriage became strained over the years, but Ballard took great joy in his boys. As soon as they were old enough, he began bringing them on expeditions, beginning with Todd, the eldest. Todd was with Ballard on the first hunt for the *Bismarck* when they didn't find the Nazi

After years of exploring the ocean on various research vessels, Ballard acquired his own, the E/V *Nautilus*, and staffed it with a crew of deep-sea discovery experts—the Corps of Exploration. In the ship's control room, Ballard examines images beamed from two underwater vehicles for signs of Amelia Earhart's airplane.

GABRIEL SCARLETT

Ballard (below right, with sister Nancy Ann and brother Richard) grew up near the ocean in Southern California with dreams of becoming like his hero, Captain Nemo from *20,000 Leagues Under the Sea*.

COURTESY ROBERT BALLARD



battleship, and he was with his father on the second try in June 1989 when they did. But three months later, Todd, not yet 21, was killed in a car crash. Ballard's marriage ended soon after.

A shattered Ballard threw himself into the JASON Project, which had launched that year and featured live broadcasts to students from an archaeology expedition in the Mediterranean—with footage provided by *Jason,* his newest ROV. Soon he'd scheduled a second *Jason* expedition to Lake Ontario and a third to the Galápagos. National Geographic was a partner in the project; the Society's point person was a young woman named Barbara Earle. In 1991 Earle and Ballard married; their children—Benjamin and Emily—would join their father on his expeditions.

Ballard was now fully in the business of finding things and taking the public along with him on his journeys. In the Mediterranean he identified an ancient trade route by the amphorae that littered the seabed, and he discovered a Phoenician ship. In the Black Sea he found a fully preserved ancient ship and evidence of a Noah-like flood. In the Pacific he located the U.S.S. *Yorktown* and Kennedy's *PT 109,* wreckage from World War II battles. He was roaming the world just as Captain Nemo did. Now all he needed was his very own *Nautilus.* He tried to buy an East German research vessel that appeared to have been outfitted as a spy ship. When he couldn't afford the asking price, the owner, New York billionaire Vincent Viola, gave it to him. Enamored by Lewis and Clark's Corps of Discovery, Ballard created a Corps of Exploration, the team that would operate the *Nautilus*'s technological tools on expeditions around the world.

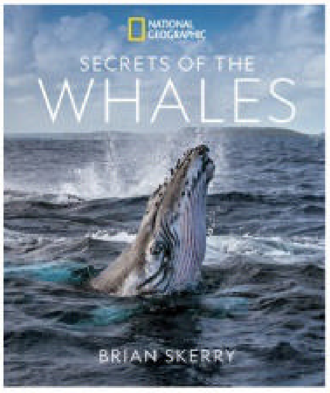
Ballard emulated Lewis and Clark in another way too. As it did with the 19th-century explorers, the U.S. government asked Ballard to map United States territory—the exclusive economic zone (EEZ) that extends 200 miles along the country's shores. That's what brought Ballard to Nikumaroro in 2019: The *Nautilus* was mapping the EEZ around American Samoa and Howland Island, the unincorporated territory where Earhart had intended to land in 1937. The EEZ assignment also has allowed Ballard to pursue a project along the California shore looking for underwater caves that may hold signs of the first humans who traveled down the coastline.

But Ballard's most compelling quest these days may be to understand himself. Throughout his life he wondered why his brain seemed to work so differently from other people's. Although he's the author of 26 books and more than 150 scholarly and popular articles, reading and writing remain a struggle.

Then, in March 2015, he heard a radio interview with the authors of a book about dyslexia. He ordered the book and read it in one sitting, crying when he was done, he says, "because it explained me to me." He realized that he'd created a world in which he could flourish, one that requires spatial thinking, or visualizing in three dimensions. He can stand in the middle of his ship's command center and transform its dozens of displays into a single image in his mind. During his first dive in *Alvin* to the *Titanic,* the submersible lost its sonar, but Ballard still knew where to go.

The ocean is "a world of total darkness, and it's not dark to me," Ballard says. "I see it." □

Rachel Hartigan, a staff writer for *National Geographic,* is working on a book about the search for Amelia Earhart.



TELEVISION, BOOKS

Series, Book Reveal Whales' Secrets

National Geographic Explorer Brian Skerry's breathtaking photographs are at the heart of *Secrets of the Whales*. That's the title of Skerry's new book, on sale April 6, and the name of National Geographic's documentary series, with filmmaker James Cameron executive producing and actor Sigourney Weaver narrating. It premieres April 22 on Disney+.

NAT GEO WILD

Visit the *Kingdom of the Polar Bears*

As winter shortens and ice recedes on Hudson Bay, a mother polar bear and her two cubs face perils brought on by climate change. Following the bear family, guide Dennis Compayre witnesses feats of survival and resilience. The two-hour TV special *Kingdom of the Polar Bears* airs April 22 at 8/7c on Nat Geo WILD.

TELEVISION

Chef Gordon Ramsay Serves Up Season 3

On a culinary mission, Ramsay dives, rappels, forages, kayaks, and fishes in search of great food. *Gordon Ramsay: Uncharted* returns for a new season May 31 at 9/8c on National Geographic.

BOOKS

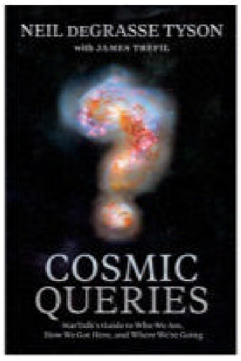
Dive Into the Life of Explorer Ballard

Known for finding famous shipwrecks such as the *Titanic,* Robert Ballard shares not only his expeditions but also his personal challenges in a remarkable memoir. *Into the Deep: An Explorer's Life* is available May 11 wherever books are sold.

BOOKS

Neil deGrasse Tyson Fields *Cosmic Queries*

Curious about your place in the universe? *Cosmic Queries: StarTalk's Guide to Who We Are, How We Got Here, and Where We're Going* offers the wit and wisdom of astrophysicist deGrasse Tyson and physicist James Trefil, illustrated with stellar photos. It's available wherever books are sold.



Subscriptions For subscriptions or changes of address, contact Customer Service at *ngmservice.com* or call 1-800-647-5463. Outside the U.S. or Canada call +1-515-237-3674.

Contributions to the National Geographic Society are tax deductible under Section 501(c)(3) of the U.S. tax code. I Copyright © 2021 National Geographic Partners, LLC I All rights reserved. National Geographic and Yellow Border: Registered Trademarks ® Marcas Registradas. National Geographic assumes no responsibility for unsolicited materials. Printed in U.S.A. I For corrections and clarifications, go to *natgeo.com/corrections*.

NATIONAL GEOGRAPHIC (ISSN 0027-9358) PUBLISHED MONTHLY BY NATIONAL GEOGRAPHIC PARTNERS, LLC, 1145 17TH ST. NW, WASHINGTON, DC 20036. $39 PER YEAR FOR U.S. DELIVERY, $44.00 TO CANADA, $51.00 TO INTERNATIONAL ADDRESSES. SINGLE ISSUE: $8.00 U.S. DELIVERY, $10.00 CANADA, $15.00 INTERNATIONAL. (ALL PRICES IN U.S. FUNDS; INCLUDES SHIPPING AND HANDLING.) PERIODICALS POSTAGE PAID AT WASHINGTON, DC, AND ADDITIONAL MAILING OFFICES. POSTMASTER: SEND ADDRESS CHANGES TO NATIONAL GEOGRAPHIC, PO BOX 37545, BOONE, IA 50037. IN CANADA, AGREEMENT NUMBER 1000010298, RETURN UNDELIVERABLE ADDRESSES TO NATIONAL GEOGRAPHIC, PO BOX 819 STN MAIN, MARKHAM, ONTARIO L3P 9Z9. UNITED KINGDOM NEWSSTAND PRICE £6.99. REPR. EN FRANCE: EMD FRANCE SA, BP 1029, 59011 LILLE CEDEX; TEL. 320.300.302; CPPAP 0725U89037; DIRECTEUR PUBLICATION: D. TASSINARI. DIR. RESP. ITALY: RAPP IMD SRL, VIA G. DA VELATE 11, 20162 MILANO; AUT. TRIB. MI 258 26/5/84 POSTE ITALIANE SPA; SPED. ABB. POST. DL 353/2003 (CONV L.27/02/2004 N.46) ART 1 C. 1 DCB MILANO STAMPA. QUAD, MARTINSBURG, WV 25401. SUBSCRIBERS: IF THE POSTAL SERVICE ALERTS US THAT YOUR MAGAZINE IS UNDELIVERABLE, WE HAVE NO FURTHER OBLIGATION UNLESS WE RECEIVE A CORRECTED ADDRESS WITHIN TWO YEARS.

PHOTOS: BRIAN SKERRY (DOLPHINS); ALEXEY SEAFARER, GETTY IMAGES (POLAR BEARS)

In just 28 days.

Purina ONE® can make a healthy eye-opening difference through powerful combinations of natural ingredients with added vitamins, minerals and nutrients.

ONE visibly healthy pet.

*Take the 28-Day Challenge at **ONE28DayChallenge.com***

PURINA® Your Pet, Our Passion.®

Trademarks owned by Société des Produits Nestlé S.A., Vevey, Switzerland.

©Inter IKEA Systems B.V. 2021
SEKTION/SINARP/HASSLARP
Kitchen
$2259
Based on a 10'×10' kitchen price
25
Year Limited
Warranty
Included
For details, visit IKEA-USA.com/warranty

Pinch salt, not yourself.

No, it’s not a dream. It’s a beautiful, sustainable and affordable quality kitchen. We even have a team of professionals to help you every step of the way, from measurement to planning to installation – even financing options. Oh, and did we mention it has a 25-year warranty? On second thought, maybe you do need that pinch.

Learn more at **IKEA-USA.com/Kitchens**

What’s included in the price? The kitchen price includes cabinets, fronts, hinges, cover panels, deco strips/moldings, legs and toekicks. All kitchens also include soft-closing hinges. Your choice of appliances, lighting, knobs/handles, sinks, faucets, countertops and interior accessories are sold separately.

GET OUTSIDE! ADVENTURE AWAITS

NATIONAL GEOGRAPHIC
ATLAS OF THE NATIONAL PARKS
JONATHAN WATERMAN
NATIONAL GEOGRAPHIC
100 PARKS 5000 IDEAS
WHERE TO GO · WHEN TO GO · WHAT TO SEE · WHAT TO DO
NATIONAL GEOGRAPHIC
Complete National Parks OF THE UNITED STATES
MEL WHITE
NATIONAL GEOGRAPHIC
100 HIKES OF A LIFETIME
The World's Ultimate Scenic Trails
NATIONAL GEOGRAPHIC
SECRETS OF THE NATIONAL PARKS
NATIONAL GEOGRAPHIC
GUIDE TO NATIONAL PARKS OF THE UNITED STATES
NINTH EDITION
NATIONAL GEOGRAPHIC
BACKYARD GUIDE TO THE NIGHT SKY
SECOND EDITION
ANDREW FAZEKAS
NATIONAL GEOGRAPHIC KIDS
NATIONAL PARKS GUIDE U.S.A.
THE MOST AMAZING SIGHTS, SCENES, & COOL ACTIVITIES FROM COAST TO COAST!

NATIONAL GEOGRAPHIC

© 2021 National Geographic Partners, LLC

AVAILABLE WHEREVER BOOKS ARE SOLD

NatGeoBooks @NatGeoBooks